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ABSTRACT

This document contains guidelines for science curriculum in Washington State schools. Statements of philosophy and program goals are presented and explained. Four major program goals (which address societal demands) operationally describe science education toward the learning of: (1) factual and theoretical knowledge; (2) applied science skills; (3) critical thinking skills; and (4) values and attitudes affecting science, the individual, and society. Learner outcomes which develop the content and intent of science education are given for the primary level (grades K-3), intermediate level (grades 4-6), Junior High/Middle School (grades 6-9), and high school (grades 9-12). Each learner outcome division includes: (1) a major program goal; (2) general objective; (3) specific learner outcome; (4) grade level; (5) instructional implications; (6) relationship between implications and outcomes; (7) content area implications; and (8) content or process related examples. Three appendices contain descriptions of science process skills, lists of resources (with addresses), and explanations of the nature and language of science (concepts, theory, and law). These guidelines are designed to be used as an information base for science program development or for analysis of existing programs. The position is given that continuing efforts be made to provide equal opportunities for every student. Suggestions are also given for instruction of limited English proficient students. (ML)

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GUIDELINES FOR SCIENCE CURRICULUM IN WASHINGTON SCHOOLS

SE 045 842

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COVER

Black Bellied Plover in Breeding Plumage
Pluvialis squatarola
10½" - 13½" 27-34 cm

Plovers are more compactly built, and thicker necked, than most sandpipers, with shorter bills and larger eyes. Whitish wing-stripe, rump, and tail, and black patch under the wing visible in flight. Found on sandy beaches and mudflats along salt water; visits open inland marshes and fresh water shores. They winter on Washington coasts.

Drawing by Tony Angell
Co-Author of Birds and Mammals of Puget Sound
University of Washington Press
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GUIDELINES FOR SCIENCE CURRICULUM

IN

WASHINGTON SCHOOLS

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FOREWORD

Science and its attendant technology have come to define a way of thinking and living that stands as a cultural signature for Americans. The scientific endeavor affects us all as it continues to provide a major frame of reference for human progress. The influence of science will not lessen during our lives. As our population enters the third millenium, it is essential to know this mode of thought and action. We must be able to participate with science and technology as knowledgeable decision makers and as competent professionals.

To this end the State Board of Education adopted in May 1983, increased graduation requirements and requested my agency to prepare program suggestions and curriculum guidelines to match the graduation requirements. The State Board of Education also stipulated that the guidelines should reflect the desire to achieve excellence across both academic and vocational areas, and to prepare students with the skills required for college and work.

Many hours have been given in order to reach consensus on these guidelines. I congratulate the educators whose names appear on the pages of this document for their excellent work. These guidelines provide a thoughtful descriptive approach to a science knowledge base, and to the skills and attitudes of basic science education for the learners of our state.

Frank B. Brouillet
Superintendent of Public Instruction

PREFACE

This curriculum tool was initiated with a decision by the Superintendent of Public Instruction, with support from both the State Board of Education and the Washington Legislature.

The Guidelines reflect many perspectives. The most significant influence throughout comes from practicing classroom teachers from all parts of Washington. They served as writers for this document. A wide variety of resources were available to those writers, but the major foundation for the direction they chose came from curriculum guidelines documents produced by State Departments of Education in Maryland, Delaware, and California. Research with Reach: Science Education, from the Appalachia Education Laboratory was used extensively, and certainly, the influence of Dr. Paul DeHart Hurd was fundamental.

The process began when teachers were recruited to participate on planning and writing teams. The real work started when they came together to establish the direction for Science Education, and to develop the details in the following pages. The working groups met at several locations throughout the state, and in every case, the people who worked on this project agreed that the kind of science education reflected here must be academically rigorous, pedagogically sound, and responsive to the needs of individuals and to their society.

We applaud their insights and thank each person who participated in the Guidelines for trenchant hard work, and especially for a significant and creative professional contribution.

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INTRODUCTION

The thought provoking ideas in these guidelines are presented with a "broad brush" approach in order that the reader may realize a more comprehensive perspective of Science Education. The developers didn't expect anyone to teach from this document, so the level of information here is quite general. Those writers and designers did expect individuals and committees to use it as an information base and for planning. Use it as you analyze existing programs, work to select a commercially developed instruction program, or to begin development of a science program for a school or a district.

The organization of information in the Guidelines begins with a science curriculum framework and is followed by statements of learner output arranged in four grade band sections; primary (K-3), intermediate (4-6), junior high/middle school (6-9), and senior high school (9-12). The detail within each grade band is hierarchial and quite straightforward. The four PROGRAM GOALS operationally describe science education in the most general terms. Each goal frames an area within science education that is responsive to the societal demands noted in the Philosphy statement on the following pages.

Each Program Goal has from four to six GENERAL OBJECTIVES that present a more finely tuned analysis of the learning necessary for Science Education, and serve to achieve that specific program goal. Both the Program Goals and General Objectives are presented together on the following pages as a FRAMEWORK which, when taken together with the philosophy, present a comprehensive perspective of the content and intent of Science Education. Beginning with the Framework, the writers looked more closely at what students should be able to do after instruction, and the implications those outcomes have on the instructional act.

LEARNER OUTCOMES describe student learning at the curriculum level, and give the reader a perspective of the student after instruction. These statements certainly don't exhaust the possibilities of student learning, but characterize one or more facets of a student's capability in relation to the goal and objective noted above.

The Goal' Objective and Learner Outcomes taken together provide a basic task analysis that should assist the readers to begin their own planning and analysis in order to develop local programs. The next level of analysis should bring the user to instructional objectives, one that is not reflected in this document.

Each Learner Outcome is matched with one or more INSTRUCTIONAL IMPLICATIONS. The Instructional Implications take up most of the space in this document; a fact that reflects the emphasis that is placed on the importance of the educators' insights into their role in helping the learner to achieve. These Instructional Implications (I.I.) are correlated to the Learner Outcomes (L.O.) by number, so where the reader sees L.O. #2, I.I. #2 below will be related directly. L.O. #3 relates specifically to I.I. #3, etc. The Instructional Implications truly follow-up the philosophical keynote that insists Science Education emphasize direct experience with natural phenomena.

A graphic example of the format and its hierarchial elements follows the Framework, and serves to provide the reader with visual clues to the organization of information in the learner outcome sections.

Three appendices are included which treat (A) Description of Science Process Skills, (B) Resources, and (C) The Nature and Language of Science. The Processes of Science, and insights into concepts, theories, and laws form a reference base that complements the Program Goals and the content base reflected in the General Objectives.

The continuing equity needs of our culture were reflected in many comments by the writing groups and review teams. Their recommendations underscore the need for continuing concrete efforts to provide equal opportunities in science education for every student. Teachers are the key to quality and equity in the school setting, and they will make the difference in how science education is able to contribute to the full development of human potential by encouraging traditionally underserved populations to take part more fully in these academic opportunities. Goal #4, Objective D speaks directly to this continuing concern.

One additional element was noted with regard to the instructional implications of equity. Bias avoidance must be a prime consideration for presenting science content to students with limited English proficiency. Teachers should consider an approach that adapts science instruction and materials to provide equivalent science experiences to limited English proficient (LEP) students. The emphasis should not be on modifying the science curriculum for LEP students, but rather on adapting instruction and materials.

The following practices are recommended:

1) assign peer tutors (native bilingual or English speaking);

2) use bilingual aides, specialists, or parents (where available);

3) first teach the vocabulary needed, then teach content;

4) emphasize hands-on activities and use of visuals; and

5) allow both oral and written responses, and evaluations in their primary language.

PHILOSOPHY

SCIENCE EDUCATION

There is clear evidence of a growing consensus in what constitutes the appropriate direction for Science Education. In addition to contributing to the development of intelligence and to the general goals of academic preparation, our society is demanding more from Science Education. Educators must continue to reflect both the scientific endeavor and the enterprise of technology acurately; in addition, we must teach all students generalizable intellectual skills such as problem solving procedures and inquiry processes in order that these skills may be applied to the real world context of personal and societal decision making.

SCIENTIFIC LITERACY

Those outcomes reflect the emergent concensus, and their achievement contributes to the development of scientifically literate citizens who understand the natural world, and how science, technology and society influence one another. As a result of that understanding, they are able to participate more effectively in their society. Scientific literacy is predicated on 1) a knowledge of the content of science, 2) competence in the processes of scientific operations, and 3) the creative capability to interpret and apply data to personal needs and societal issues.

TECHNOLOGY

Technology on one hand deals with elements of design, and its application to the built environment. It involves a synthesis of knowledge and skills from the sciences and the humanities in pursuit of practical tasks.

SCIENCE

On the other hand, science is the product and process of the efforts of humans to understand the natural world. Beginning with the assumption that nature is not capricious, people observe the natural world and through a creative, rational process of inquiry, they construct inferences that organize their experiences and identify relationships. This process develops scientific knowledge, progressively building on earlier knowledge and experiences. But, scientific knowledge remains tentative. It is always subject to revision required by new observations that do not fit the old theory and by new, simpler, rational organizations of existing observations. Scientific ideas and processes are communicated to other segments of culture for the dual purposes of developing general understanding of the world around them and applying the understanding to the betterment of life for all participants in the ecosystem.

THE ROLE

The role of Science Education in the overall program of studies, in addition to helping develop applied intellectual capability, is to serve an integrating role between and among disciplines and to reinforce learning in other subject matter areas. By coupling the understanding of scientific subject matter itself with the insights gained in mathematics, social studies and the humanities, the goals of general education may be more effectively achieved.

Bonaparte's Gull in Breeding Plumage
Along the Saratoga Passage in Puget Sound
Larus philadelphia
12" - 14"
Drawing by Tony Angell

SCIENCE CURRICULUM GUIDELINES
FRAMEWORK

GOAL #1

DEVELOP AND APPLY KNOWLEDGE OF OBSERVATIONAL FACTS, CONCEPTS, PRINCIPLES, THEORIES, AND PROCESSES OF SCIENCE.

A. Acquire the techniques of using the processes of scientific inquiry.

B. Practice applying the knowledge of the content of the major scientific disciplines in areas of life, physical, chemical, and earth/space science.

C. Demonstrate understanding of some basic generalizations, relationships, and principles applied to all sciences.

D. Enhance problem solving skills by analyzing social/environmental and technological problems.

GOAL #2

DEVELOP SKILLS IN MANIPULATING MATERIALS AND EQUIPMENT, AND IN GATHERING AND COMMUNICATING SCIENTIFIC INFORMATION.

A. Assemble and handle laboratory apparatus, tools, materials and living organisms in a skilled and responsible manner, giving due attention to safety.

B. Gather qualitative and quantitative information.

C. Record observations accurately and organize data and ideas in ways that enhance their usefulness.

D. Apply appropriate mathematical concepts and skills in interpreting data and solving problems.

E. Communicate with others in a manner that is consistent with scientific reporting.

F. Identify sources of error, inconsistencies in measurements, and other threats to the validity of findings.

GOAL #3

DEVELOP AND APPLY RATIONAL, CREATIVE AND CRITICAL THINKING SKILLS.

A. Acquire the ability to collect and process data.

B. Acquire the ability to generate ideas.

C. Apply ideas and/or data to situations and problems.

D. Uses procedures for checking generated ideas and solutions.

E. Anticipate future situations and problems.

GOAL #4

DEVELOP VALUES, ASPIRATIONS, AND ATTITUDES THAT PROMOTE PERSONAL INVOLVEMENT OF THE INDIVIDUAL WITH THE ENVIRONMENT AND SOCIETY.

A. Acquire a positive realistic self-concept.

B. Acquire an awareness and appreciation of beauty and orderliness in nature.

C. Participate actively in identifying and solving societal problems related to science and technology.

D. Acquire knowledge of the interrelationships between science, politics, economics, religion, and other aspects of culture.

E. Acquire an appreciation for science related careers and science learning throughout one's life.

A GUIDE TO THE DESIGN AND USE OF LEARNER OUTCOME PAGES

1. PROGRAM GOAL: Identifies one of four major areas of the science education program.

2. GENERAL OBJECTIVE: Describes the learning in the most general terms.

3. LEARNER OUTCOME: What we want the student to know, be able to do or have an attitude about after instuction.

4. GRADE LEVEL

SPI--SCIENCE CURRICULUM GUIDE 9-12

GOAL #2: DEVELOP SKILLS IN MANIPULATING MATERIALS AND EQUIPMENT, AND IN GATHERING AND COMMUNICATING SCIENTIFIC INFORMATION.

OBJECTIVE D. Apply appropriate mathematical concepts and skills in interpreting data and solving problems.

LEARNER OUTCOME 1. Apply appropriate algebraic, geometric, and statistical techniques to manipulate data.
2. Use measured data to derive mathematical expsressions to describe phenomena.
3. Manipulate appropriate mathematical relationships to solve problems.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
The teacher should provide opportunities:			
1. to review math skills such as dimensional analysis and give examples of how the data can be manipulated through math procedures. Collect data and apply to:			
i.e. pendulum law Newton's laws	Perfect Gas Laws	population dynamics such as growth rate densities, and distribution	hydrostatic equation, heat capacity of water, latent heat of fusion and evaporation
2. for the student to manipulate data & generate a mathematical relationship, e.g.:			
i.e. centripetal force experiments, current, resistence and potential difference in electricity	Charles' Law Calorometric experiments	Enzymatic reactions vs. temperature changes	water wave speed experiment, absorption of light in water for different wave lengths, using P and S waves to determine the locus of an earthquake
3. to apply mathematical principles to solve problems in science, e.g.:			
i.e. calculates rates in motion experiments	Derive molar volumes from measurements of gas collected in a stoichiometric reaction.	calculates population trends from data-Hardy Weinberg equation, surface to volume ratios of cells	Calculate Doppler shift by measuring rate of shift toward the red end of spectrum.

5. INSTRUCTIONAL IMPLICATIONS: Issues that teachers may consider in designing instructional programs.

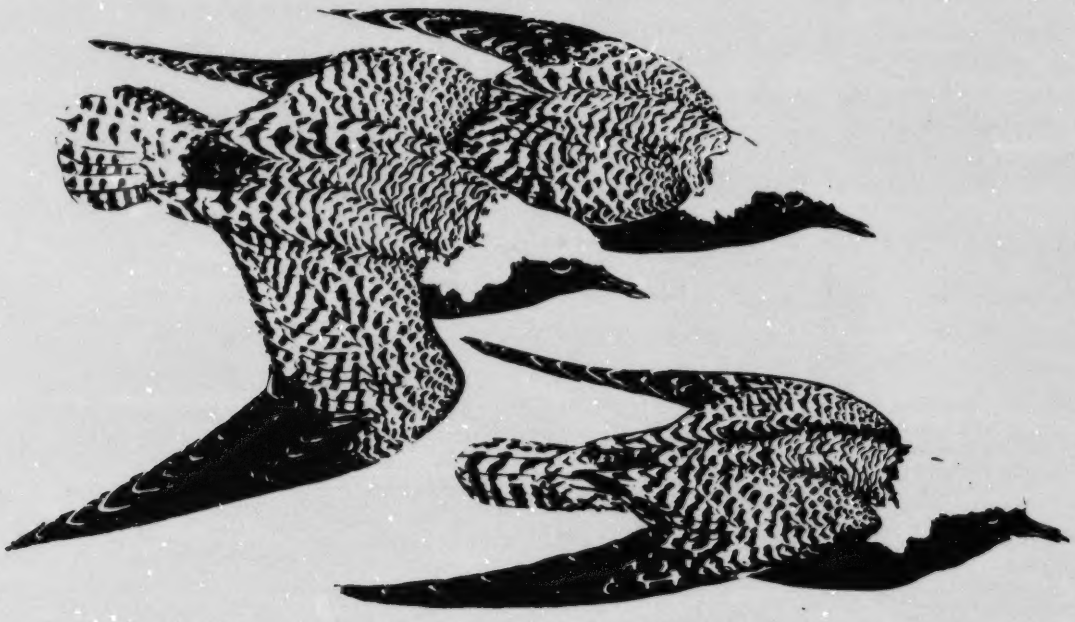
6. Direct relationship exists between each instructional implication and the learner outcome of the same number.

7. Implications that apply to all four content areas.

8. By way of illustration an example is provided to clarify the meaning of the I.I.

LEARNER OUTCOMES

PRIMARY
K-3



Black Bellied Plover
Drawing by Tony Angell

SPI--SCIENCE CURRICULUM GUIDE K-3

GOAL #1: DEVELOP AND APPLY KNOWLEDGE OF OBSERVATIONAL FACTS, CONCEPTS, PRINCIPLES, THEORIES, AND PROCESSES OF SCIENCE.

OBJECTIVE: A. Acquire the techniques of using the processes of scientific inquiry.

LEARNER OUTCOME:
1. Students learn to make observations using all their senses.
2. Students learn to classify data on the basis of their observations.
3. Students learn to use numbers to order data in a logical, meaningful and sequential manner.
4. Students learn to communicate data in written and oral form.
5. Students learn to discuss their observations.
6. Students learn to formulate explanations for observed events.
7. Students learn to interpret data based on new information.
8. Students learn to predict a result based on known data.
9. Students learn to modify a prediction based on new data.
10. Students learn to test predictions through experimentation.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE
1. Provide ample and varied experiences for students (e.g. field trips, activities).		
2. Provide opportunities for students to group objects according to previously agreed upon criteria.		
3. Provide a variety of charts and graphs for students to practice recording data.		
4. Alow time for students to report orally and in written form, results of observations.		
5. Organize small groups to share and compare their recorded observations and discuss differences and similarities.		
6. Teacher will provide many opportunities to generate explanations (inferences) based on known data.		
i.e. Put iron nails in a glass of water overnight. Inference: Metals change/react in water.	Prepare several seeds by putting some on a dry paper towel and some on towel that is kept damp Inference: Water is necessary for seeds to grow.	Beaches and streams contain sand. Where does this come from? Inference: Sand comes from the breakdown of other rocks.
7. Teacher will help students reinterpret known data based on additional information.		
i.e. Put a new penny in same glass of water. Inference: Not all metals change.	Put some of the germinated seeds in soil and leave some on the paper towel. Inference: Soil provides a food that is necessary for seeds to grow.	Observe that sandstone or conglomerate is made up of small pieces of rock. Inference: Some rocks are made of sediment (pieces of other rocks).* *Students can break apart a piece of sandstone to demonstrate.
8. Teacher will guide students to make predictions based on known data.		
i.e. Predict iron will rust (change/react), but copper will not change.	Predict that water and soil (& sunlight) are necessary for plants to grow and thrive.	Predict all rocks/minerals are hard.
9. Teacher will encourage students to modify a prediction based on new data.		
i.e. Keep a new penny in water for a week. The penny will tarnish (react). Inference: Some metals react faster than others.	Put a fern in direct sunlight or overwater a seed or plant. Infer that an excess of basic needs can damage or destroy some forms of life.	Observe that some rocks/minerals are softer than others.
10. Teacher will help students set up experiment to test their prediction.		
i.e. See how long it takes for different metals to react.	Test several plants for their tolerance to direct sunlight or total darkness.	Test the hardness of various rocks/minerals by using a fingernail, nail, penny and glass.

SPI--SCIENCE CURRICULUM GUIDE K-3

GOAL #1: DEVELOP AND APPLY KNOWLEDGE OF OBSERVATIONAL FACTS, CONCEPTS, PRINCIPLES, THEORIES, AND PROCESSING OF SCIENCE.

OBJECTIVE: B. Practice applying the knowledge of the content of the major scientific disciplines in areas of life, physical, chemical, and earth/space sciences.

LEARNER OUTCOME: 1. Students gain knowledge in the areas of physical science, life science and earth/space science.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE
1. Teachers will provide opportunities for students to observe, explore, experiment and relate ideas to promote understanding in the major science content areas.		
i.e. states of matter, reactions of matter, concepts of light, magnetism, electricity, and force and motion	structure, function, and diversity of plants and animals, ecological relationships	weather, earth materials, marine environment and space

OBJECTIVE: C. Demonstrates understanding of some basic generalizations, relationships, and principles applied to all sciences.

LEARNER OUTCOME: 1. Students gain knowledge that will lead to an understanding of basic natural cycles and systems.
2. Students learn concepts of form and patterns such as; circles, polygons, chains, grids, spirals, etc.
3. Students understand the basic concepts of communities (integrate with social studies).

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE
1. Structure hands on experiences and group discussion opportunities leading to the development of an understanding of basic cycles and systems.		
i.e. watercycles	life cycles of butterfly, frog, etc.	seasonal cycle, solar system, water cycle
2. Teacher will provide hands on experiences and group discussion opportunities leading to the development of an understanding of form and pattern.		
i.e. crystal growth	cell growth, sea shells	snowflakes
3. Teacher will provide hands on experiences and group discussion opportunities leading to the development of an understanding of communities and their needs.		
i.e. polution	food webs, pond life	ecology

GOAL #2: DEVELOP SKILLS IN MANIPULATING MATERIALS AND EQUIPMENT, AND IN GATHERING AND COMMUNICATING SCIENTIFIC INFORMATION.

OBJECTIVE: A. Assemble and handle laboratory apparatus, tools, materials and living organisms in a skilled and responsible manner, giving due attention to accident prevention.

LEARNER OUTCOME: 1. Student learns to use measuring tools calibrated in standard U.S. and metric systems to collect data in a skilled manner.
2. Student learns to operate and use equipment in a safe manner when doing science.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE
1. Organize frequent opportunities for students to use appropriate scientific equipment.		
i.e. thermometers, stopwatch, scale, measuring cups, anemometer		
2. Regularly provide instruction in safety related to science activities and materials.		
i.e. heat can burn, unknown substances should not be tasted	some plants are toxic animals may bite	rocks can injure

OBJECTIVE: B. Gather qualitative and quantitative information.

LEARNER OUTCOME: 1. Students learn to use observation skills for data collection, and organizational skills to order qualitative and quantative information from a variety of sources.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE
1. Teacher will provide many concrete activities for student involvement.		
i.e. similarities and differences between states of matter (solids, liquids, gasses)	similarities and differences between living and non-living organisms identify and count populations of living things	environmental changes as rainfall, cloud patterns, errosion, air temperature

OBJECTIVE: C. Record observations accurately and organize data and ideas in ways that enhance their usefulness.

LEARNER OUTCOME: 1. Students learn to record and organize data and ideas in a useful manner.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE
1. Create and utilize a variety of record keeping devices for the students such as graphs, diagrams, charts, etc.		
i.e. changes in the states of matter, weights and sizes of objects	living & non-living things in the classroom	weather changes

SPI--SCIENCE CURRICULUM GUIDE K-3

GOAL #2: DEVELOP SKILLS IN MANIPULATING MATERIALS AND EQUIPMENT, AND IN GATHERING AND COMMUNICATING SCIENTIFIC INFORMATION.

OBJECTIVE: D. Apply appropriate mathematical concepts and skills in interpreting data and solving problems.

LEARNER OUTCOME: 1. Students learn to apply mathematical skills and concepts to interpret data and solve problems.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE
1. Make available an abundance of problem-solving activities leading to the understanding and use of strategies such as the following:		
a. -- looking for and using patterns;		
b. -- constructing tables, charts, and graphs;		
c. -- using estimation skills;		
d. -- making organized lists:		
e. -- acting out problem situations;		
f. -- guessing, testing, and evaluating;		
g. -- drawing a picture or making a model of a machine or a process;		
h. -- solving a simpler or similar problem;		
i. -- brainstorming;		
j. -- looking for counter examples;		
k. -- working backwards from results.		
i.e. measure the amout of time it takes for ice to melt to a liquid and for water to change to steam using a constant heating rate	count the number of living & non-living things in the classroom -- divide into related groupings	compare shapes, color, density, and texture of rocks

GOAL #2: DEVELOP SKILLS IN MANIPULATING MATERIALS AND EQUIPMENT, AND IN GATHERING AND COMMUNICATING SCIENTIFIC INFORMATION.

OBJECTIVE: E. Communicate with others in a manner that is consistent with scientific reporting.

LEARNER OUTCOME: 1. Students will learn to communicate data in written forms (graphs, diagrams, equations, words) and through oral discussion.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE
1. Provide opportunities for students to use mathematical skills and concepts to communicate data by:		
a. writing a statement explaining and reporting their findings.		
b. orally interpreting trends and relationships from graphs describing living and non-living objects and processes.		
i.e. weight of objects versus size of objects made from uniform material	width of tree growth rings versus years	use weather chart to report the number of sunny days or rainfall and temperature pattern in the month

OBJECTIVE: F. Identify sources of error, inconsistencies in measurements, and other threats to the validity of findings.

LEARNER OUTCOME: 1. Students learn that it is easy to make errors when doing science if extreme care is not used.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE
1. Provide opportunities for comparison of results leading to an understanding that one must check for error (accuracy of equipment, human error, personal bias).		
i.e. students build and use barometers and compare findings against commercial barometers and local published weather data	students measure weight to height ratios or wrist diamater to forearm length of classmates	students record weather data and compare findings

SPI--SCIENCE CURRICULUM GUIDE K-3

GOAL #3: DEVELOP AND APPLY RATIONAL, CREATIVE AND CRITICAL THINKING SKILLS.

OBJECTIVE: A. Acquire the ability to collect and process data.

LEARNER OUTCOME: 1. Students will understand how data collecting and organization skills are used to obtain and order information.

INSTRUCTIONAL IMPLICATIONS

PHYCIAL SCIENCE	LIFE	EARTH/SPACE
1. Teacher will provide opportunities for students to collect data and utilize graphs, diagrams, and charts to record their observations.		
i.e. collect data on relationships between water level in a glass and the tones produced or weights and lever arms with a simple balance beam	collect seeds and classify according to specified characteristics	weather observations changes in tide level

OBJECTIVE: B. Acquire the ability to generate ideas.

LEARNER OUTCOME: 1. Students will understand how creative thinking processes are used to generate ideas.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE
1. Teachers will provide oral discussion topics (brainstorming) to develop a variety of ideas, addressing a common problem.		
i.e. how to divide, manage, and use water and energy resources of the earth		

OBJECTIVE: C. Apply ideas and or data to situations and problems.

LEARNER OUTCOME: 1. Students will understand how data and rational thinking processes are applied to solving a variety of situations or problems.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE
1. Teachers will provide opportunities for students to review information, set up a problem, and use questioning strategies to propose solutions.		
i.e. magnets, simple levers baking bread	pros and cons of feeding birds in the winter irrigation and crop production	solar energy relationship between sun and earth, use of solar heating

GOAL #3: DEVELOP AND APPLY RATIONAL, CREATIVE AND CRITICAL THINKING SKILLS.

OBJECTIVE: D. Use procedures for checking generated ideas and solutions.

LEARNER OUTCOME: 1. Students will recognize the value of subjecting data and ideas to others for testing and review.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE
1. Teacher will provide small-group opportunities for students to practice having their ideas and data reviewed, checked and/or edited by others.		

OBJECTIVE: E. Anticipate future situations and problems.

LEARNER OUTCOME: 1. Students will understand how questioning and creative thinking strategies are used to predict possible future situations and problems.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE
1. Use questioning and creative thinking strategies to encourage students to predict future situations and problems.		
i.e. heat bottle with balloon attached to opening	simulate caterpiller going through life cycle	build a model spacecraft, list necessary supplies

SPI--SCIENCE CURRICULUM GUIDE K-3

GOAL #4: TO DEVELOP VALUES, ASPIRATIONS, AND ATTITUDES THAT PROMOTE PERSONAL INVOLVEMENT OF THE INDIVIDUAL WITH THE ENVIRONMENT AND SOCIETY.

OBJECTIVE: A. Acquire a positive realistic self-concept.

LEARNER OUTCOME: 1. Achieve attitudes and behaviors of a self-directed learner.
2. Demonstrates and values personal decision making.
3. Relate concepts of science to their own world.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE

1. Provide opportunities to carry out a project/experiment independently.

   i.e. hands on items to be explored in a science corner

2. Provide opportunities for students to carry out a project/experiment in a small group setting.

3. Provide numerous individual and small group opportunities for students to question factual knowledge; classify observations, organize data, and participate in an experiment; use graphs, forms and charts to collect data; and use their new collected data to form an original conclusion.

OBJECTIVE: B. Acquire an awareness and appreciation of beauty and orderliness in nature.

LEARNER OUTCOME: 1. Enhances the desire to question, know and understand the natural world.
2. Encourages a sense of wonder about the environment.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE

1. Capitalize on situations that promote questions and small group discussions and sharing about the natural world.

2. Create an atmosphere through personal example and activities that promote increased appreciation of the environment.

OBJECTIVE: C. Participate actively in identifying and solving societal problems dependent on science and technology.

LEARNER OUTCOME: 1. Develop cooperative skills in working within a group.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE

1. Introduce social and environmental problems within the range of student experience to be discussed in group settings.

   i.e. alternative energy sources — hunger — erosion

   pollution — population rates and controls — drought

   check kitchens and bathrooms with a parent for toxic chemicals

GOAL #4: TO DEVELOP VALUES, ASPIRATIONS, AND ATTITUDES THAT PROMOTE PERSONAL INVOLVEMENT OF THE INDIVIDUAL WITH THE ENVIRONMENT AND SOCIETY.

OBJECTIVE: D. Acquire knowledge of the interrelationships between science, politics, economics, religion, and other aspects of culture.

LEARNER OUTCOME: 1. An awareness of science as an activity of humans from all racial, ethnic and cultural backgrounds.
2. Recognition that scientific inferences are affected by the value system of the observer.
3. Value science as a participant in the potential improvement of the human condition.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE
1. Use visual materials, filmstrips and posters, and books to stimulate small group discussions.		
i.e. simple machines used to enhance life styles	role of doctors and medicine	irrigation
2. Provide opportunities for students to make identical observations and share their interpretations.		
i.e. describe smell or taste of a common but unseen material in container (e.g. lemon, onion)	observe a living organism and share descriptions of observed behavior in discussion	observe a stream as a habitat
3. Provide concrete examples of how science can improve the human condition by involving students in discussion with representatives from different career fields.		
i.e. engineering	farming	irrigation or flood control.

OBJECTIVE: E. Acquire an appreciation for science related careers and science learning throughout ones life.

LEARNER OUTCOME: 1. Consideration of science as future oriented, preparing individuals for a fuller, richer and more effective life.

INSTRUCTIONAL IMPLICATIONS

PHYSICAL SCIENCE	LIFE	EARTH/SPACE
1. Provide students with guest speakers and role playing opportunities.		
i.e. electrician, engineer, lab technician, computer engineer	doctor, vet, biologist paramedic	geologist, space scientist, meteorologist, oceanographer

LEARNER OUTCOMES

INTERMEDIATE
Grades 4-6

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Bonaparte's Gull
Drawing by Tony Angell

GOAL #1: DEVELOP AND APPLY KNOWLEDGE OF OBSERVATIONAL FACTS, CONCEPTS, PRINCIPLES, THEORIES, AND PROCESSES OF SCIENCE.

OBJECTIVE: A. Acquire the technique of applying knowledge of the processes of scientific inquiry.

LEARNER OUTCOME: 1. Ability to use basic investigative techniques and processes when conducting a scientific investigation:

INSTRUCTIONAL IMPLICATIONS/RESOURCES

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Guide the students through the basic technques associated with science, such as:			
OBSERVATION			
i.e. types of energy	paper chromatography	sensory bags (hidden objects)	stargazing constellations
CLASSIFYING			
i.e. types of energy	paper chromatography	plant leaves; children in class	rocks
MEASURING			
i.e. pendulum swings	paper chromatography	plant growth; physical characteristics of children	sun shadow plots
IDENTIFYING AND CONTROLLING VARIABLES			
i.e. ice cube melt	paper chromatography	animal characteristics and adaptations	sun shadow plots with seasonal variations
INFERRING			
i.e. bubble activities (different wire forms and bubble shape)	paper chromatography	animal tracks	sun shadows seasonal variations
PREDICTING OUTCOMES			
i.e. bubble activities (different wire forms and bubble shape)	paper chromatography	eating habits and bird beak shapes	sun shadows
APPLYING KNOWLEDGE			
i.e. energy conservation	paper chromatography	terrariums, bird feeders, bird houses	rocket launching paper airplanes

OBJECTIVE: B. Practice applying the knowledge of the content of the major scientific disciplines in the areas of Life, Physical, Chemical, and Earth/Space Sciences.

LEARNER OUTCOME: 1. The student matches activities and subject areas to their respective scientific disciplines.

INSTRUCTIONAL IMPLICATIONS/RESOURCES

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Give students information about distinguishing features and areas of emphasis of the main scientific branches.			

GOAL #1: DEVELOP AND APPLY KNOWLEDGE OF OBSERVATIONAL FACTS, CONCEPTS, PRINCIPLES, THEORIES, AND PROCESSES OF SCIENCE.

OBJECTIVE: C. To produce an understanding of some basic generalizations, relationships, and principles applied to all sciences.

LEARNER OUTCOME: 1. The student will be able to identify systems in nature that involve principles common to all science.

INSTRUCTIONAL IMPLICATIONS/RESOURCES

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Give students resources for studying systems in nature.			
i.e. water cycle, changes in the state of water and other substances	water cycle, acid rain	water cycle, plant growth	water cycle, evaporation/condensation density layers in lakes and the ocean

OBJECTIVE D. Enhance problem solving skills by analyzing social-environmental and technological problems.

LEARNER OUTCOME: 1. Acquire an ability to apply rational and creative thinking processes to individual problems, and to general technological and environmental problems.

INSTRUCTIONAL IMPLICATIONS/RESOURCES

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Give students opportunity to identify and solve			
a. individual problems			
i.e. water faucet repairs	proper nutrition	personal hygiene	compass use map and survival skills
b. technological and environmental problems			
i.e. transportation systems, alternate energy sources	pollution, pesticide use	wetland and wilderness, preservation	airport/airtraffic noise polution

GOAL #2: DEVELOP SKILLS IN MANIPULATING MATERIALS AND EQUIPMENT, AND IN GATHERING AND COMMUNICATING SCIENTIFIC INFORMATION.

OBJECTIVE: A. Assemble and handle lab apparatus, tools, materials, and living organisms in a skilled and responsible manner giving due attention to accident prevention.

LEARNER OUTCOME: 1. Recognition of the proper and safe use of equipment.
2. Students will learn to maintain a proper environment for the healthy maintenance of all living organisms.

INSTRUCTIONAL IMPLICATIONS/RESOURCES

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Provide materials and equipment needed for simple experiments.			
i.e. be able to use balances, dry cells, levers, and magnets	be able to use graduated cylinders, litmus paper, and glassware	be able to use microscopes, magnifying glasses	be able to use magnifying glasses, directional compasses, simple weather instruments and maps
2. Provide plants and/or animals needed for simple experiments and/or maintenance.			
i.e. show effects of light, sound, temp., and safe enclosure of plants and animals	show effects of various chemicals and nutrients on plants and animals	show ability to properly feed and water plants and animals	show effects of water and soil on plants and animals

OBJECTIVE: B. Gather qualitative and quantative information.

LEARNER OUTCOME: Students will make measurements and produce a written record of their data, such as; size, number, and type of observations.

INSTRUCTIONAL IMPLICATIONS/RESOURCES

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Supply tables, graphs, charts, data sheets as data sources and for recording data taken in experiments.			
i.e. record data obtained from experiments using pendulums and levers	record properties of substances through observation of crystalline structure, smell, magnetic influence, burning and filtering	record rate of plant growth, animal population, bacteria growth in cultures	record data from the use of simple weather instruments, measure evaporation rate, analyze mineral characteristics

OBJECTIVE: C. Record observations accurately and organize data and ideas in ways that enhance their usefulness.

LEARNER OUTCOME: 1. Develops an ability to organize information in various graphic and tabular forms.

INSTRUCTIONAL IMPLICATIONS/RESOURCES

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Give students materials for measuring and recording data and guide them in constructing tabular and graphic displays of measured quantities.			
frequency counts, period of oscillation of weighted springs	yeast cultures, changing pH values of safe acids with safe bases	population counts	barometric pressure, rainfall, wind chill factor

GOAL #2: DEVELOP SKILLS IN MANIPULATING MATERIALS AND EQUIPMENT, AND IN GATHERING AND COMMUNICATING SCIENTIFIC INFORMATION.

OBJECTIVE: D. Apply appropriate mathematical concepts and skills in interpreting data and solving problems.

LEARNER OUTCOME: Acquire an ability to apply the four arithmetic operations to physical events; to calculate rates, and to find arithmetic means of measurements.

INSTRUCTIONAL IMPLICATIONS/RESOURCES

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Give students instruction in the use of collected data.			
i.e. variations of pitch using stretched strings or wires of different lengths, tension or diameter	use ratios and proportions in mixtures and recipes	construct growth chart to predict future height and weight	measure height of tree by use of shadow length relative to shadow length of an object of known height

OBJECTIVE: E. Communicate with others in a manner that is consistent with scientific reporting.

LEARNER OUTCOME: 1. Ability to explain both orally and in writing the methods and procedure involved in carrying out an investigation.

INSTRUCTIONAL IMPLICATIONS/RESOURCES

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Give students opportunities, resources and encouragement to explain their experiment as well as those of others.			
i.e. use science fairs to present steps and data taken in investigation use films and articles that demonstrate or discuss scientific use interviews with people in the community involved with science for use developing in reports			

OBJECTIVE: F. Identify sources of error, inconsistencies in measurements, and other threats to the validity of findings.

LEARNER OUTCOME: 1. Ability to identify sources of error in the experimental process.

INSTRUCTIONAL IMPLICATIONS/RESOURCES

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Give groups of two or three students the opportunity to carry out the same experiment and have students search for causes of variations in results.			
i.e. measure temperature of beaker of hot water at 5 minute intervals as it cools	vary experimental conditions of paper chromatography	measure heights of plants, look at ruler to find descrepancies	measure shadow lengths of identical sticks as noon approches to find the time of shortest shadow, the local noon suntime

GOAL #3: DEVELOP AND APPLY RATIONAL, CREATIVE AND CRITICAL THINKING SKILLS.

OBJECTIVE: A. Acquire the ability to collect and process data.

LEARNER OUTCOME: 1. The student will be able to generate data by observing, identifying, measuring and recording.

INSTRUCTIONAL IMPLICATIONS/RESOURCES

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Give students opportunites to generate and use data.			
i.e. by recording changes of magnetism in a reversing electric current	mystery powders, identification of common substances	pulse-rate before and after recess	mass and weight of matter using specific volumes of water

OBJECTIVE: B. Acquire the ability to generate ideas.

LEARNER OUTCOME: Student will be able to put observations together through the use of analogy, correlation between patterns, discrepancies, synthesis, logic and mathematical relations.

INSTRUCTIONAL IMPLICATIONS/RESOURCES

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Give students opportunities to identify data that supports, contradicts, or does not apply to the solution of a problem.			
i.e. create a simple machine that solves a problem	change several pieces of matter into different forms; describe the methods necessary to restore the materials to their original form	reconstruct an animal skeleton	plot a trip on a roadmap that describes the most efficient way to get to a destination

OBJECTIVE: C. Apply ideas and or data to situations and problems.

LEARNER OUTCOME: 1. Ability to use patterns and trends derived from experimental data as a basis for examining related problems.

INSTRUCTIONAL IMPLICATIONS/RESOURCES

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Expose students to brainstorming sessions where given data is applied to varied situations.			
i.e. pulleys and levers voltage and magnetism light and shadows and temperatures	acid rain pollution toxic chemical substances	population growth greenhouse effect energy flow in living systems bacterial contamination of water systems	earthquake predictions affect of paving on storm water run off to streams

GOAL #3: DEVELOP AND APPLY RATIONAL, CREATIVE AND CRITICAL THINKING SKILLS.

OBJECTIVE: D. Use procedures for checking generated ideas and solutions.

LEARNER OUTCOME: 1. Student will be able to check assumptions and consider the reasonableness of solutions to problems.

INSTRUCTIONAL IMPLICATIONS/RESOURCES

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Give students opportunities to identify data contrary to expectations to and test alternative solutions.			
i.e. pulleys and levers on a 10 speed bicycle	mystery powders, identification of common substances that are toxic	population growth and predator-prey relationships	soil type influence on plant growth with or without fertilizer

OBJECTIVE: E. Anticipate future situations and problems.

LEARNER OUTCOME: Students gain ability to organize, interpret, and predict future outcomes based on observations and from available data.

INSTRUCTIONAL IMPLICATIONS/RESOURCES

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Give students exposure to brainstroming techniques that elicit conceptually rich predictions of future events based upon theory or trend.			
i.e. predict swing periods of various pendulum lengths, strength of electromagnets with increased number of windings	chemical dependancies, solubility of materials in common, but in different liquids	providing food for astronauts, plant growth and yield as related to nutrient supply and/or irrigation	alternative forms of energy considering need versus availability of sources

GOAL #4: TO DEVELOP VALUES, ASPIRATIONS, AND ATTITUDES THAT PROMOTE PERSONAL INVOLVEMENT OF THE INDIVIDUAL WITH THE ENVIRONMENT AND SOCIETY.

OBJECTIVE: A. Acquire a positive realistic self-concept.

LEARNER OUTCOME: 1. Achieve attutudes and behaviors of a self-directed learner.
2. Completes, successfully, a self-inititated classroom investigation.
3. Completes, successfully, an individual science project.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Give student opportunities to work independently.			
i.e/ weighing air, making a rheostat	crystal growing and recording of related observations	growing seeds in different soils	weather chart analysis for wind patterns and types of fronts
2. Give student opportunities for individual investigation.			
i.e. investigate relationship between strength of electro-magnet and number of wire turns	conduct iodine test for presence of starch in various foods	compare effectiveness of 5 toothpastes in retarding bacteria growth in petri dishes	use binoculars to observe/ record features of Earth's moon; phases of venus
3. Organize a science fair using parental help.			
make a model of an electric motor	grow and mount various crystals for display	make a maze for small animal learning experiment	collect and classify rocks

OBJECTIVE: B. Acquire awareness and appreciation of beauty and orderliness in nature.

LEARNER OUTCOME: 1. Creates a desire to question, know, and understand the natural world.
2. Develop a sense of wonder about the environment.
3. Express feelings about the aesthetic aspects of the natural and technological environment.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Give students opportunities for investigation/prediction.			
i.e. predicting, counting water drops that can be added to a "full" glass of water.	extraction of natural dyes by boiling roots, leaves, etc. in alcohol/water/ diluted vinegar	find examples of fibonacci sequence in plant life	observe varieties of crystal patterns in snowflakes
2. Provide students with opportunities to observe novel phenomena.			
i.e. air pressure crushes gallon can	electrolysis of water (liquid compound transformed into gaseous elements)	microscopic study of pond water	daytime observation of moon with binoculars
3. Give students opportunities for art/writing activities based on nature and technology.			
i.e. draw pictures of mechanical objects (trucks, aircraft, farm implements)	write poems about the continuous making/unmaking of organic/inorganic forms	sculpt clay models of life forms	construct pictures of solar system or one of its parts

GOAL #4: DEVELOP VALUES, ASPIRATIONS, AND ATTITUDES THAT PROMOTE PERSONAL INVOLVEMENT OF THE INDIVIDUAL WITH THE ENVIRONMENT AND SOCIETY.

OBJECTIVE: C. Participate actively in identifying and solving societal problems related to science and technology.

LEARNER OUTCOME: 1. Student will be able to identify problems in their immediate environment that result from the impact of science and technology.
2. Students will participate constructively in a group science activity.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Give students opportunities for large and small group investigations and/or reports.			
i.e. dangerous machines, toys, types and forms of energy	pesticides, weed retardants, chemical additives in food products	genetic engineering, artificial organs	storage of nuclear waste, strip mining, clear cutting, pollution
2. Give (2-4) students opportunities to role play reports.			
i.e. dangerous machines, toys, types and forms of energy	pesticides, weed retardants, chemical additives in food products	genetic engineering, artificial organs	storage of nuclear waste, strip mining, clear cutting, pollution

OBJECTIVE: D. Acquire knowledge of the interrelationships between science, politics, economics, religion and other aspects of culture.

LEARNER OUTCOME: 1. The student will value science as an activity of humans from all racial, ethnic and cultural backgrounds.
2. Students will recognize that scientists may make the identical observations but interpret them differently according to their value systems.
3. Students will be able to give examples of how science has contributed to the mental and physical well being of people and society.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Give students various ethnic, gender, and multicultural science materials both International and American.			
i.e. Alexander G. Bell. Marie Curie Albert Einstein	Booker T. Washington Linus Pauling	Jonas Salk Gregor Mendel Jane Goodall Louis Pasteur	Benjamin Banneker Astronauts John Wesley Powell Herbert Hoover
2. Give students examples of groups with opposing self-interests.			
i.e. nuclear energy	dangerous chemicals pesticides	Tobacco Industry National Institute of Health drugs	nuclear waste storage space litter
3. Give students resources that deal with contributions of science to society.			
i.e. machine use	chemical & drug uses	nutritional study	space technology

SPI--SCIENCE CURRICULUM GUIDE 4-6

GOAL #4: TO DEVELOP VALUES, ASPIRATIONS, AND ATTITUDES THAT PROMOTE PERSONAL INVOLVEMENT OF THE INDIVIDUAL WITH THE ENVIRONMENT AND SOCIETY.

OBJECTIVE: E. Acquire an appreciation for science related careers, and science learning throughout ones life.

LEARNER OUTCOME: 1. Students will considere science and technology as a career choice.

INSTRUCTIONAL IMPLICATIONS/RESOURCES

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Teachers should expose students to the variety of roles and opportunities present in science and technological fields using reports, films, role playing, and guest speakers.			

LEARNER OUTCOMES

JUNIOR HIGH/MIDDLE SCHOOL
Grades 6-9

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Black Bellied Plover
Drawing by Tony Angell

SPI--SCIENCE CURRICULUM GUIDE 6-9

GOAL #1: DEVELOP AND APPLY KNOWLEDGE OF OBSERVATIONAL FACTS, CONCEPTS, PRINCIPLES, AND PROCESSES OF SCIENCE.

OBJECTIVE: A. Acquire the technique of applying knowledge of the processes of scientific inquiry.

LEARNER OUTCOME: 1. Student will use the following processes when conducting a scientific investigation:
a. observation
b. organization
c. communication
d. inference
e. prediction
f. application

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Provide opportunities for students to conduct scientific experiments/investiations, i.e.:			
a. Observe incline areas on school property, e.g., ramps, gutters.	Observe mixtures, elements and compounds.	Observe freshly cut carrot and celery sticks.	Observe samples of crystals.
b. Record results on data chart.			
c. Draw a picture of one incline plane on school property.	Describe and record physical characteristics of mixture, element and compound samples.	Describe and record the texture of freshly cut carrot and celery sticks.	Describe the physical characteristics of a crystal to another person.
d. Inferences are derived from observations and past experiences.			
e. Make a prediction about the height and its relationship to the amount of work accomplished when moving an object on an incline plane.	Given the time required to dissolve salt in cold water, predict the time required to dissolve in hot water.	Predict the effect of salt on the properties of living tissue.	Make predictions on the variables affecting crystal growth.
f. List 6 uses of incline planes to make work easier.	Identify 5 examples of mixtures, elements and compounds found in the home.	Explain how salt can be used as a weed killer.	Give 5 examples of crystal usage in a student's environment.

GOAL #1: DEVELOP AND APPLY KNOWLEDGE OF OBSERVATIONAL FACTS, CONCEPTS, PRINCIPLES, AND PROCESSES OF SCIENCE.

OBJECTIVE: B. Practice applying the knowledge of the content of the major scientific disciplines in areas of life, physical chemical, and earth/space science.

LEARNER OUTCOME: 1. For each content area the student will be able to use appropriate facts, concepts and vocabulary.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Teacher will use process approach including: a. observation b. inferences c. prediction d. measurement e. experiment f. organize/classify g. communication h. application			
i.e. Content areas recommended for use and presentation in student syllabus: A. Methods of science B. Measurement C. Properties of matter D. Forces E. Motions F. Energy 1. heat, light, sound 2. electric 3. magnetism 4. kinetic/potential 5. chemical/physical 6. nuclear	Content areas recommended for use and presentation in student syllabus: A. Methods of science B. Atomic theory C. Elements/Compounds Mixtures D. Changes: nuclear physical and chemical E. Acids, bases, salts F. Reactions G. Organic H. Inorganic I. Environmental	Content areas recommended for use and presentation in student syllabus: A. Methods of science B. Life characteristics 1. cell theory 2. origin of life 3. inorganic/organic chem. 4. plant and animal protist distinctions 5. levels of organization 6. reproduction 7. genetics 8. natural selection C. Ecosystems 1. adaptations 2. pollution 3. energy flow, food chain, web and pyramid 4. cycles of nature	Content areas recommended for use and presentation in student syllabus: A. Methods of science B. Map reading C. Topography D. Geological time scale E. Plate-tectonics F. Erosion G. Properties of minerals H. Rocks/minerals I. Meteorology J. Oceanography K. Natural resources L. Space

GOAL #1: DEVELOP AND APPLY KNOWLEDGE OF OBSERVATIONAL FACTS, CONCEPTS, PRINCIPLES, AND PROCESSES OF SCIENCE.

OBJECTIVE: C. To produce an understanding of basic generalizations, relationships, and principles applied in all sciences.

LEARNER OUTCOME: 1. Student will be able to:
a. use inferences to make generalizations
b. recognize and predict patterns
c. state laws
d. formulate explanatory models
e. develop theories

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Expose students to a variety of knowledge/experiences that will allow them to discover interrelationships within the sciences.			
Show how atomic structure applies to all sciences.			
movement of electrons to produce energy	atomic structure	photosynthesis as a chemical process	atomic structure of crystals
Show that energy is changed from one form to another.			
solar to electric energy	endothermic and exothermic reactions	food (chemical energy) is changed to muscle movement	fossil fuels to heat
Use Newton's 3 laws of motion to understand and explain space travel.	Demonstrate how conservation of matter applies to the cycling of substances in nature.	Use the principles of natural selection to explain plant and animal adaptation.	Use theory of plate tectonics to explain formation of oceanic island chains, ridges, and trenches.
	Examples are carbon dioxide-oxygen, water and nutrient cycle.	Examples are flightless birds, protective coloration, and mimicry.	

OBJECTIVE: D. Enhance problem solving skills by analyzing social, environmental and technical problems.

LEARNER OUTCOME: 1. Student will recognize the relevancy of science by using scientific knowledge, processes and methods to:
a. clarify values
b. examine isues
c. solve scientific, personal and societal problems

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Provide resources for analytical investigation and research:			
i.e. Research and evaluate nuclear fusion/fission, reactions.	Analyze and determine the use of synthetic materials, i.e., synthetic materials vs. biodegradable products, i.e. plastic.	Analyze the trade-off involving the protection of valued natural resources, i.e.,spraying for tussock moths at expense of other wildlife.	Research and evaluate man's reversible and irreversible causes of natural disaster, i.e., soil erosion depleting water table.

SPI--SCIENCE CURRICULUM GUIDE 6-9

GOAL #2: DEVELOP SKILLS IN MANIPULATING MATERIALS AND EQUIPMENT, AND IN GATHERING AND COMMUNICATING SCIENTIFIC INFORMATION.

OBJECTIVE: A. Assemble and handle laboratory apparatus, tools, materials and living organisms in a skilled and responsible manner giving due attention to accident prevention.

LEARNER OUTCOME: The student will develop fundamental skills in:
a. orderliness
b. safe manipulation of materials and equipment
c. caring for and handling living things

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. (a, b)			
Provide lab materials, equipment, guidelines for use, and safety instruction.			
i.e. Use a triple beam balance.	Make volume measurement using a graduated cylinder.	Use a microscope.	Use a meteorology tool.
1. (b, c)			
Post, demonstrate and enforce appropriate lab and safety procedures.			
i.e. Wear goggles and/or aprons in lab.	Demonstrate eye wash.	Clean aquariums.	Return tools to storage areas.
Keep work areas clear.	Designate as tasting and nontasting activity.	student responsibility for classroom animal and plant maintenance	Note safety precautions in lab directions.

OBJECTIVE: B. Gather qualitative and quantitative information.

LEARNER OUTCOME: 1. The student will develop measurement skills that allow for comparisons using:
a. sensory
b. relative position
c. linear
d. weight
e. capacity
f. quantity

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Provide resources, practice measuring, and instruction in the metric system.			
i.e. Determine a student's weight in pounds and Newtons.	Determine density using the displacement method.	Determine in microns the field of view of a microscope.	Weigh 3 rock samples in grams and ounces.
Determine a student's height in centimeters and meters.	Determine the relative saltiness of 4 salt solutions.	Determine the number of chlorophyll types present in a leaf by chromatographic technique.	Determine the relative size and properties of minerals in a piece of granite.

GOAL #2: DEVELOP SKILLS IN MANIPULATING MATERIALS AND EQUIPMENT, AND IN GATHERING AND COMMUNICATING SCIENTIFIC INFORMATION.

OBJECTIVE: C. Record observations accurately and organize data and ideas in ways that enhance their usefulness.

LEARNER OUTCOME: 1. The student will develop organizational skills in:
a. gathering
b. sequencing
c. grouping
d. classifying data
e. graphing
f. charting

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. (a, b, c)			
Provide instruction and models in building appropriate data collection devices.			
i.e. Sequence different mediums according to how they refract light.	Given a set of procedural instructions, construct a data table.	Match seeds with the plants that produce them.	Chart temperature, barometric pressure, relative humidity, rainfall, wind speed, etc., for one week.
1. (c, d)			
Provide material for grouping.			
i.e. Rank a number of objects according to velocity they can attain with a constant force.	Classify household chemicals according to their pH.	Given 10 objects, build a dichotomous key.	Given information on the planets, group them accordingly: i.e., orbital period; distance from sun; mass to gravity.
1. (e, f)			
Provide examples of various graphs and graph paper.			
Make a line graph to show the relationship between speed and time.	Graph the temperature of water as it changes from solid to liquid to gas.	Make a bar graph of the heights of students in the class.	Graph the weather conditions at your school for one week.

GOAL #2: DEVELOP SKILLS IN MANIPULATING MATERIALS AND EQUIPMENT, AND IN GATHERING AND COMMUNICATING SCIENTIFIC INFORMATION.

OBJECTIVE: D. Apply appropriate mathematical concepts and skills in interpreting data and solving problems.

LEARNER OUTCOME: 1. Use measured data and/or mathematical model to describe observed phenomena.
2. Use basic math skills to solve scientific problems.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Provide instruction in the use of a formula to describe a process and solve problems by using formulas.			
i.e. Using the law of universal gravitation, determine the gravitational force between earth and student.	Use the formula for density to determine density of a given object. K=M/V	Determine a population density. D = No. of indiv./area.	Identify a mineral by calculating its specific gravity. SP.G.- $\frac{\text{density of substance}}{\text{density of water}}$
Determine the amount of work a person did by applying a force of 10 Newtons to move a box 6 meters.	Demonstrate the use of the perfect gas law.	Demonstrate how populations increase with different reproduction rates.	Demonstrate hydrostatic pressure effects.
Work = Force x Distance W = D x F D = 6m F = 10N W = F x D W = 10N x 6M W = 60NM			
2. Provide review materials and instruction in basic mathematical operations, i.e., percentages, rounding, estimating, significant figures, metric units, ratios and decimal operations.			

GOAL #2: DEVELOP SKILLS IN MANIPULATING MATERIALS AND EQUIPMENT, AND IN GATHERING AND COMMUNICATING SCIENTIFIC INFORMATION.

OBJECTIVE: E. Communicate with others in a manner that is consistent with scientific reporting.

LEARNER OUTCOME: 1. Students achieve communication skills which will enable them to express themselves.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE

1. Develop a formal lab report form using the following divisions:
   a. Clear statement of the problem stated in question form,
   b. State the purpose,
   c. List the materials and relevant data,
   d. Write the procedural steps,
   e. Experimental analysis, i.e., data chart and observation,
   f. Write a conclusion based on the statement of purpose.

OBJECTIVE: F. Identify sources of error, inconsistencies in measurement and other threats to validity of findings.

LEARNER OUTCOME: 1. Ability to find source of variation in the results of experimentation that occur from human error, instrument error, and experimental error.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE

1. After a lab, provide lists of possible sources of error.
   i.e., Human error: Reading the instrument and/or processing directions.
   Instrument error: Graduation on the tool may be incorrect.
   Experimental error: Insufficient number of trials.

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GOAL #3: DEVELOP AND APPLY RATIONAL, CREATIVE AND CRITICAL THINKING SKILLS.

OBJECTIVE: A. Acquire the ability to collect and process data.

LEARNER OUTCOME: 1. Communication skills which will enable them to express themselves orally, pictorially, and in writing.
2. Develop organization skills in gathering, sequencing, grouping and classifying data.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Present students with a problem that requires senses to gather information and have them discuss their findings.			
i.e. black box puzzles	black box puzzles	mercury amoeba	examine rock properties
2. Have students make collections and catalog them.			
i.e. Group items according to their properties of matter.	Group items according to their properties of matter.	Determine whether items are living or nonliving based on the characteristics of living things.	Given several rocks, arrange them in groups based on similar properties.
Sequence a group of appliances from greatest to least energy consumption.	Based on physical characteristics, group substances as mixtures, compounds and elements.	Make a collection of leaves and group according to common characteritics.	Plot location of earthquakes and volcanoes.

OBJECTIVE: B. Acquire the ability to generate ideas.

LEARNER OUTCOME: 1. Students will be able to put observations together through the use of:
a. analogy
b. correlation
c. patterns
d. discrepancies
e. synthesis
f. logic
g. mathematical relationships

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Provide topics and opportunities for brainstorming possible hypotheses.			
i.e. cartesian diver, crystal growth, osmosis/diffusion, formation of land form, perpetual motion models for atoms, origin of life theories, solar system models machines			
Develop an efficient measuring system. Reorganize the periodic chart. Describe a living system without photosynthetic organisms. Describe the climate zones on an earth without an axis tilt.			

GOAL #3: DEVELOP AND APPLY RATIONAL, CREATIVE AND CRITICAL THINKING SKILLS.

OBJECTIVE: C. Apply ideas and/or data to situations and problems.

LEARNER OUTCOME: 1. Recognition of the relevancy of science by using scientific knowledge processes and methods to clarify values, examine issues, and solve scientific, personal, and social problems.
2. Application of scientific knowledge (technology) to satisfy personal curiosity or solve a problem.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Provide brainstorming sessions to formulate three alternatives to solving a problem.			
i.e. Devise 3 different ways to move an object.	pest control	drug/alcohol/tobacco usage	use of vacant lots in urban and rural settings
2. Demonstrate or justify how to use an alternative solution to a problem.			
i.e. Build a solar hot dog cooker.	Use of natural predators as an alternative or chemical pesticide	Increase physical activities in order to improve personal health.	Build homes on hillsides and retain flat fertile soil for agriculture.

OBJECTIVE: D. Use procedures for checking generated ideas and solutions.

LEARNER OUTCOME: 1. Ability to design and conduct experiments, construct classification schemes and identify factors that might have influenced conclusions.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Teachers will provide necessary reference resources and equipment, and assist in the recognition of experimental discrepancies and procedural differences.			
i.e. Control the frequency of the sound produced by a vibrating string.	Identify common materials by physical and chemical properties.	Contruct experiments on osmosis, diffusion, plasmolysis.	Construct a physical model from a contour map.
Construct a musical instrument.	Separate solids from liquids in a mixture by sedimentation.	Test effects of moisture, temperature, oxygen or light on seed germination and seed growth.	Locate, measure and draw a scale chart of land features.
Construct series and parallel electrical circuits.		Construct a classification scheme, grouping organisms according to personally defined criteria.	
		Identify factors which cause changes or imbalances in natural or model environments.	

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GOAL #3: DEVELOP AND APPLY RATIONAL, CREATIVE AND CRITICAL THINKING SKILLS.

OBJECTIVE: E. Anticipate future situations and problems.

LEARNER OUTCOME: 1. Anticipates future consequences of present actions by applying cause and effect relationship.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Give a hypothetical situation with available data for students to use in making predictions.			
depletion of energy resources	accumulation of contaminants in the environment	over population of man or animal	depletion of natural resources
use of solar, wind, or wave energy as an option	use of fossil fuels for energy or as building blocks for other products, i.e., petrochemicals	Predict future of protected plant and animal species that are endangered.	recycling of nonrenewable resources and waste disposal

GOAL #4: TO DEVELOP VALUES, ASPIRATIONS, AND ATTITUDES THAT PROMOTE PERSONAL INVOLVEMENT OF THE INDIVIDUAL WITH THE ENVIRONMENT AND SOCIETY.

OBJECTIVE: A. Acquire a positive realistic self-concept.

LEARNER OUTCOME: 1. Achieve attitude and behaviors of a self-directed learner.
2. Demonstrates and values personal decision making.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Provide opportunities for individual and team activities.			
i.e. List machines and type of energy used in one day, determine which ones could be eliminated. Discuss hidden energy needs of products.	Bring or list cosmetics used daily to change body scent. Note chemicals used in food products.	Make 2-5 minute sensory observation during quiet time outside; make observations of personal effects of sensory inputs.	Make observation of home in relationship to community and local climate pattern.
2. Provide real and hypothetical situations/problems.			
i.e. Redesign two machines using a renewable energy resource.	Invite cosmetologist to discuss hair chemistry, product ingredients and care.	Conservation activity, i.e. research FDA or EPA regulation for specific problem.	List and discuss need for moon survival.

GOAL #4: TO DEVELOP VALUES, ASPIRATIONS, AND ATTITUDES THAT PROMOTE PERSONAL INVOLVEMENT OF THE INDIVIDUAL WITH THE ENVIRONMENT AND SOCIETY.

OBJECTIVE: B. Acquire awareness and appreciation of beauty and orderliness in nature.

LEARNER OUTCOME:
1. Enhance the desire to question, know and understand the natural world.
2. Encourage a sense of wonder about the environment.
3. Help focus feelings about asthetic aspects of the natural and technological world.
4. Gain an appreciation interdependence of living organisms is necessary for their continued survival in the natural environments.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1.A. Reward students for asking questions.			
B. Provide field experience.			
i.e. Observe sight rays through a variety of optic systems, i.e., prisms, lenses.	Observe environment from edge of body of water.	Investigate a specific plot of ground for living organisms.	Observe geological structure and soil types at a roadcut.
2. Provide student with examples and opportunities to describe and discover natural patterns.			
i.e. Construct a color spectrum.	Compare salt and sugar crystals.	Compare leaf margins and veination of different plants.	Draw a soil profile.
3. Provide a setting and mood that will enhance student expression.			
i.e. Listen to sounds outside for 1 minute with eyes closed, identify sounds heard, direction traveled etc. Open eyes, write and discuss feelings.	Conduct flame test of metals in solution. Discuss how colored flame fireplace logs work.	Brainstorm examples of man's impact on wildlife, i.e., trace foods back to their source, identify impact on wildlife along the way to consumer; recommend food habits that could benefit wildlife.	Accumulate rocks from local area and have students explain origin, shape, texture and appearance. Use guided imagery.
4. Provide students with materials designed to demonstrate the interdependency in nature.			
i.e. "Powers of 10"	"Chemistry and Nature" Centron Film	"Ark" "Endless Chain"	"The Earth Beneath the Sea" McGraw Hill Film "We are of the soil: International Film Bureau"

GOAL #4: TO DEVELOP VALUES, ASPIRATIONS, AND ATTITUDES THAT PROMOTE PERSONAL INVOLVEMENT OF THE INDIVIDUAL WITH THE ENVIRONMENT AND SOCIETY.

OBJECTIVE: C. Participate actively in identifying and solving societal problems related to science and technology.

LEARNER OUTCOME: 1. Develops cooperative skills in working within a group.
2. Ability to express an opinion on societal issues using knowledge of science and technology to support that opinion.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Design and use activities that require interaction.			
i.e. Groups establish to priorities for a list of issues centered around a scientific-technological problem and come to a consensus, i.e., use of lasers for weapons, biological warfare, five necessities for survival in a space shuttle.			
2. Identify issues, provide resources for investigation, and choose mode of expression i.e., debate, speech, report, role play, etc.			
i.e. Generalize the implications of removing one major appliance from every home of class members.	Predict the impact on society as a result of removing preservatives from food products.	Predict tendency for heart disease after researching risk factors and individual history.	Discuss the liabilities and assets of the space program and/or land storage of hazardous waste products.

OBJECTIVE: D. Acquire knowledge of the interrelationships between science, politics, economics, religion and other aspects of culture.

LEARNER OUTCOME: 1. Students will understand by examples how science has contributed to the mental and physical health and well being of people.
2. Value science as an activity available to males and females from all racial, ethnic, and cultural backgrounds.
3. Recognition that scientific influences are affected by the value system of the observer.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Provide for guest speaker or field experience.			
i.e. laser technology and computers	Examine value of chemical fertilizers, food additives, etc., to increase food production.	Discuss genetic engineering and choices it brings in life decisions.	Examine how environmental science is used in planning land use.
2. Provide names, photographs and biographical material of scientists.			
i.e. Report on the contributions of scientists from a variety of ethnic and cultural backgrounds, such as:			
Chien Shiung Wu Mr. & Mrs. Curie	Ellen Swallow	George Washington Carver	Galileo Maria Mitchell Amelia Earhart
3. Provide examples of disproved explanatory models based on today's information.			
i.e. perpetual motion machines	alchemy	spontaneous generation	geocentric theory

GOAL #4: TO DEVELOP VALUES, ASPIRATIONS, AND ATTITUDES THAT PROMOTE PERSONAL INVOLVEMENT OF THE INDIVIDUAL WITH THE ENVIRONMENT AND SOCIETY.

OBJECTIVE: E. Acquire an appreciation for science related careers and science learning throughout ones life.

LEARNER OUTCOME: 1. Consideration of science as future oriented, preparing individuals for a fuller, richer and more effective life.
2. Students will consider science and technology as a career choice.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. Provide students with the opportunity to select a career and investigate the impact of science/technology on this career choice.			
2. Provide an opportunity for students to interview an individual in a science related career.			
i.e. mechanical engineer	pharmacist, chemical engineer	horticulturalist agri-business medicine	meteorologist geologist oceanographer

LEARNER OUTCOMES

HIGH SCHOOL
Grades 9-12

Bonaparte's Gull
Drawing by Tony Angell

GOAL #1: DEVELOP AND APPLY KNOWLEDGE OF OBSERVATIONAL FACTS, CONCEPTS, PRINCIPLES, THEORIES, AND PROCESSES OF SCIENCE.

OBJECTIVE: A. Acquire the technique of applying knowledge of the processes of scientific inquiry.

LEARNER OUTCOME:
1. Make accurate measurements and observations.
2. Form hypotheses from both quantitative and qualitative observations.
3. Use experimental procedures to confirm or reject hypotheses.
4. Integrate observations and experimental results with scientific ideas.
5. Subject results and conclusions to critical evaluation by self and others.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
The teacher should provide opportunities:			
1. a. to use metric system in collecting data			
i.e. acceleration, forces, calorimetry	density, temperature, volume, identify unknowns and concentrations of solutions	serial dilutions; measuring plan growth; microscopy	density; specific gravity temperature; pressure
b. to read instruments accurately to appropriate level of precision			
i.e. micrometer, Vernier scale	graduate cylinders pipets	microscope micrometer	hygrometer, hydrometer, and barometer
c. for experiences that will give opportunity to record observations on a regular basis			
2. a. for students to write hypotheses on which data will be collected, such as:			
i.e. nature of light based on observation of light phenomena, hypothesize the general properties of a field from the nature of gravity magnetics, and electrostatics.	stoichiometric calculations; use Gas Laws to predict behavior of gases	plasymolysis of cells; ratio of surface to volume of cells and diffusion	surface characteristics of ground compared to absorption of heat energy; centripetal motion compared to orbital velocity of satellite
3. for students to design and carry out experiments to test a hypothesis			
i.e. measurement of variation in potential difference and current flow in electrical circuits designed by the students	Design experiments to measure solubility of inorganic salts as a function of temperature.	determining conditions necessary to grow seeds from edible fruits purchased in a store; explain changes in a yeast culture, hay infusion, or daphnia aquarium.	determine the rate of erosion in a stream using a stream table by varying velocity and volume of water flow.
4. to compare results of experiments with concept taught			
i.e. expansion of metals as a function of temperature	pH of solutions as compared to pH meter or titrations	snail, elodea, closed aquarium experiment compared with CO_2 and O_2 cycles	soil characteristics as compared to water storage and movement
5. a. Compare results of an experiment with results of classmates as well as with knowledge of concept being tested.			
i.e. Compare the results of the pendulum swing with the weight of the bob and the length of the pendulum with other students.	Compare the gravimetric results in a conservation of matter exercise.	comparing blood typing results with other students and national trends	identification of unknown minerals using standard tests
b. for students to submit written lab reports to peer review and evaluation by instructor			
c. for students to enter experimental results in contests for evaluation, such as Junior Science and Humanities Symposium, national or state science contests			

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GOAL #1: DEVELOP AND APPLY KNOWLEDGE OF OBSERVATIONAL FACTS, CONCEPTS, PRINCIPLES, THEORIES, AND PROCESSES OF SCIENCE.

OBJECTIVE: B. Practice applying the knowledge of the content of the major scientific disciplines in the areas of Life, Physical, Chemical and Earth/Space Sciences.

LEARNER OUTCOME: PHYSICS

1. Accurately predict what will happen during physical events.
2. Accurately describes physical phenomena in terms of materials and wave properties.
3. Explain phenomena, appropriately applying ideas of interaction and conservation.
4. Develop and use an appropriate scientific vocabulary.
5. Develop a set of meaningful ideas of the natural world which are more convincing and more powerful than the ideas held before instruction.

INSTRUCTIONAL IMPLICATIONS

PHYSICS

The teacher should provide opportunities:

1. for students to observe and recall basic phenomena and predict results under similar circumstances;

   i.e. falling bodies,
   apparent motions of sun, moon, stars, and planets,
   forces and distance involved with simple machines,
   magnetics, electrostatics, current electricity and electromagnetic interactions,
   waves on water and springs,
   sound,
   light and optics

2. for students to describe systems and subsystems using ideas of time intervals, position, displacement, speed, velocity (both average and instantaneous), mass, momentum, energy, charge, wave length, frequency, period, amplitude, and phase.

3. a. to require students to explain phenomena during interactions; such as drawing free body force diagrams, determining impulses on or by each object involved, and determine work done on or by each part of system

   b. to require students to explain changes using conservation laws, transfers between forms of energy

4. a. to guide students to develop ideas first and that the name given to that idea is used for purpose of communication. i.e. the name is not the idea, but only represents the idea

   b. to guide students in the clear use of scientific vocabulary (see Appendix B)

5. for students to investigate and demonstrate an understanding of physical processes and concepts;

   i.e. the kinematic ideas of time intervals, position, displacement, speed, velocity (both average and instantaneous), change in velocity, acceleration (average and instantaneous),
   forces the energy transfer to explain movement of objects in various contexts (including the "at rest" condition, constant velocity, straight line acceleration, free fall and projectile motion, circular motion, and simple harmonic motion,
   the daily, monthly, and annual motions of the stars, moon, sun, and planets, as observed from the earth,
   the major contributions of the acients (e.g. Plato, Aristotle, Aristarcus, Ptolemy, Copernicus, Tycho Brahe, Kepler, Galileo, and Newton) in organizing the observations into classical views of the cosmos,
   motions (their causes and effects) from different frames of reference that may be in motion relative to each other,
   electric and magnetic phenomena,
   demonstrate an understanding of forces, electrical potential difference, resistance, and current to explain electrical phenomena,
   wave characteristics, including wave length, frequency, speed, amplitude, phase, and propagation in a medium,
   wave phenomena, including transmission, reflection, refraction, diffraction, interference, dispersion, images, and sources,
   conservation laws, including mass, momentum, energy and electrical charge,
   qualitatively the nature of space, time, and matter under the assumption of constancy of the speed of light with respect to any reference frame, and
   the phenomena that led human kind to a belief in the electron and other constituents and properties of the atom.

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GOAL #1: DEVELOP AND APPLY KNOWLEDGE OF OBSERVATIONAL FACTS, CONCEPTS, PRINCIPLES, THEORIES, AND PROCESSES OF SCIENCE.

OBJECTIVE: B. Practice applying the knowledge of the content of the major scientific disciplines in the areas of Life, Physical Chemical and Earth/Space Sciences.

LEARNER OUTCOME: BIOLOGY

1. Develop and use appropriate biological facts, concepts, and vocabulary.
2. Understand the molecular and cellular aspects of living things.
3. Demonstrate knowledge of the systems of living organisms.
4. Demonstrate knowledge of the relationship between structure and function of living organisms.
5. Understand species continuation.
6. Recognize interrelationships between living and non-living systems.
7. Understand that diversity and adaptation allow for change through time.
8. Understand the systematic grouping of organisms.
9. Understand the factors influencing behavior of organisms.

INSTRUCTIONAL IMPLICATIONS

LIFE

The teacher should provide opportunities:

1. to learn appropriate vocabulary used in each major biological concept and learn qualities and characteristics of each concept or term, such as: DNA -- its location, function, relevance, position and relationship to life

2. a. to observe cells as single living independent units and as part of a larger whole. Experiences in experimenting with the chemical functions of living things, such as detecting starch production in plants, detecting digestion in saliva

   b. to explore the use of the DNA code in an activity, such as constructing a protein model

   c. to compare and contrast mitosis and meiosis, such as modeling with pipe cleaners to identify stages on slides

   d. to solve problems using principles or genetics, such as: dominance, independent assortment, linkage, and human genetic disorders

3. a. to identify with parts of a system within a living organism:

      i.e. circulatory system with heart, lungs, veins, arteries, blood, etc.,
      vascular tissue, including xylem, phloem, seive tubes, etc., and
      reproductive system

   b. to explore factors that influence the efficient functioning of the system, such as:

      i.e. exercise
      smoking
      diet
      life style
      disease

   c. Compare similar systems in different organisms, such as: the circulatory in humans, frogs, grasshoppers to illustrate both open and closed systems.

4. to observe the relationship of structures and functions of things

   i.e. plant and animal cells with attention to cell wall and chloroplasts
   shape of plant leaves and function they serve with attention to leaf thickness and location of stomata
   shape of bird beak and the type of food it eats

5. a. to observe and compare sexual and asexual reproduction, such as yeast and hydra budding, flower dissection and seed production

   b. to compare methods of development, such as: metamorphosis and embryological processes in chicks and starfish

LIFE

OBJECTIVE B. BIOLOGY Continued

6. a. to experiment with energy in living systems

i.e. photosynthesis, use different colored lights; different intensities of light, germination of seeds; varying temperature, number of hours of light, etc., fermentation and the making of cheese and yogurt, model building using ATP, and design a food chain and web, including water cycle and decomposers

b. to explore relationship of abiotic system on an organism

i.e. relating flora and fauna to altitude, and biome determination factors

c. to explore the parameters with which living systems can exist

i.e. competition for food and shelter, carrying capacity of the land, and temperature range

d. to explore the impact of humans on the environment

i.e. pest control through the use of insecticides, and acid rain

7. a. to examine evolutionary theories of Lamark, Darwin, Gould, and etc.

b. to study examples of change through time

i.e. camouflage, geographic isolation, and structural adaptation, such as teeth of carnivores and herbivores, or the development of Equus.

8. a. to create a dichotomous classification key

b. Use a classification key to separate organisms into logical groupings.

c. Use an existing taxonomy key to classify organisms.

i.e. Northwest conifers, marine snails, desert wildflowers

d. to observe characteristics of the major kingdoms

9. a. to experiment with environmental stimuli on organismal behavior

i.e. geotropism, phototropism, animal response to temperature change, such as crickets, mating behavior of animals, and color changes in organisms, such as fiddler crabs and chameleons.

b. to study instinctive and learned behavior

i.e. territoriality in guinea pigs, and mice in mazes

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GOAL #1: DEVELOP AND APPLY KNOWLEDGE OF OBSERVATIONAL FACTS, CONCEPTS, PRINCIPLES, THEORIES, AND PROCESSES OF SCIENCE.

OBJECTIVE: B. Practice applying the knowledge of the content of the major scientific disciplines in the area of Life, Physical, Chemical, and Earth/Space Sciences.

LEARNER OUTCOME: CHEMISTRY

1. Accurately predict what will happen during chemical events.
2. Accurately describe chemical phenomena and changes in physical and chemical properties of matter.
3. Understand elementary atomic structures and the regularities in the Periodic Table.
4. Develop and use an appropriate scientific vocabulary.

INSTRUCTIONAL IMPLICATIONS

CHEMISTRY

The teacher should provide opportunities:

1. a. for the student to make qualitative predictions of results of chemical reactions based upon the elementary reaction classifications of single displacement, decomposition, double displacement and synthesis

   b. to make quantitative predictions of the results of chemical reactions based on stoichiometric principles

2. to observe and describe physical and chemical properties of matter and the changes that occur as a result of chemical properties of matter

3. a. to become familiar with the modern model of the nuclear atom and atomic theory

   b. to understand the statistical nature of the electron and the significance of the orbital concept

   c. to develop the historical context of major theories, such as: atomic theory, oxidation, electrostatics, etc.

   d. to understand the significance of the atomic number and chemical periodicity as protons are added to nuclei

4. to learn appropriate chemical terminology using operational definitions developed in the context of the laboratory and discussion, rather than relying upon a glossary or dictionary

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GOAL #1: DEVELOP AND APPLY KNOWLEDGE OF OBSERVATIONAL FACTS, CONCEPTS, PRINCIPLES, THEORIES, AND PROCESSES OF SCIENCE.

OBJECTIVE: B. Practice applying the knowledge of the content of the major scientific disciplines in the area of Life, Physical, Chemical, and Earth/Space Sciences.

LEARNER OUTCOME: EARTH/SPACE SCIENCE

1. Develop and use an appropriate scientific vocabulary.
2. Understand the interactions of matter and energy in processes within meteorology, astronomy, geology and oceanography in describing and explaining natural phenomena occuring in earth and space.

INSTRUCTIONAL IMPLICATIONS

EARTH/SPACE SCIENCE

The teacher should provide opportunities:

1. for the student to develop a working knowledge of the appropriate earth/space terminology

i.e. in GEOLOGY:

to relate the process of rock formation to changes in time, temperature and pressure
to relate disastrophism, mountain building, and rock cycle
to investigate dynamic processes that change the earth's crust

in ASTRONOMY:

to study the birth and death of stars in the universe
to explore the properties of the interaction between the members of the solar system, galaxy, and the rest of the universe, such as: constellations, gravitational interactions between celestial bodies, and black holes

in METEOROLOGY:

to explore the effect of the sun's heat on earth-wind pattern development
to explore the dynamic interactions between the atmosphere, hydrosphere, and lithosphere, such as the water cycle, wind patterns, jet stream, and weather

in OCEANOGRAPHY:

to study the effect of waves on beach building and coastal composition and appearance
to explore the dynamic changes within the ocean, and processes that control salinity, density and turbidity currents, light penetration, and zonation

2. for the student to develop an understanding of processes and their underlying basic principles

i.e. in GEOLOGY:

to predict the future of the major landforms on earth based on continental drift and plate tectonics

in ASTRONOMY:

to recognize the impact of the moon on tides.

in METEOROLOGY:

to recognize that weather is a function of changes in heat, pressure, and earth's rotation.

in OCEANOGRAPHY:

to understand how sea surface processes like heating, cooling, evaporation and precipitation control the vertical structure and circulation of the oceans

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GOAL #1: DEVELOP AND APPLY KNOWLEDGE OF OBSERVATIONAL FACTS, CONCEPTS, PRINCIPLES, THEORIES, AND PROCESSES OF SCIENCE.

OBJECTIVE: C. To produce an understanding of some basic generalizations, relationships, and principles applied to all sciences.

LEARNER OUTCOME:
1. Recognize that most events in nature occur in a predictable way and are understandable in terms of cause-and-effect relationships.
2. Understand that natural laws are universal and are demonstrated throughout time and space.
3. Recognize that through classification systems, scientists bring order and unity to apparently dissimilar and diverse natural phenomena.
4. Understand the tentative nature of science.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
The teacher should provide opportunities:			
1. a. for experimenting with predictable events, testing cause-and-effect relationships			
i.e. lighting of bulbs in circuits falling bodies motion under known forces	rates of chemical reactions chemical equilibrium phase changes: melting and boiling points	photosynthesis germination study of a yeast or daphnia population enzyme actions osmosis	planetary motion tides erosion
b. to observe that events carried out under the same conditions yeild reproducable results. e.g. Acid-base titrations, gravimetric experiments.			
c. to see that laws are applicable universally, such as: (see Appendix B)			
i.e. law of gravity behavior of light relativity of space and time	statistical nature of matter thermodynamics electrostatics kinetic theory	laws of inheritance laws of conservation of mass and energy universal use of ATP	law of gravity hydrodynamics thermodynamics
3. for experimentation that will allow students to develop and use classification systems that demonstrate order and unity in nature, such as:			
i.e. field theory density of sinking and floating objects	equilibrium electro-chemistry and redox chemical periodicity	biochemistry atomic theory, e.g. molecules in osmosis; DNA replication taxonomy	identification of objects in the outside of this solar system classification of rocks; landforms geologic time
4. for the student to realize that science is a dynamic process that changes with understanding			
i.e. absolute space time vs. relevant time	Thompson, Bohr, and quantum mechanics models of the atom	Lamarck, Darwin, and Gould	Ptolemy, Copernicus

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GOAL #1: DEVELOP AND APPLY KNOWLEDGE OF OBSERVATIONAL FACTS, CONCEPTS, PRINCIPLES, THEORIES, AND PROCESSES OF SCIENCE.

OBJECTIVE: D. Apply the content and processes of science to the understanding of social, environmental and technological problems.

LEARNER OUTCOME:
1. Identify existing and potential problems.
2. Gather data relevant to the problem.
3. Evaluate opinions and proposed solutions.
4. Analyze data to better understand the problem, to form an opinion, or to propose solutions.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE

The teacher should provide opportunities:

1. for students to identify current social, environmental and technological conditions presently causing problems or having the potential to cause future problems

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
i.e. nuclear products: waste disposal transportation handling accidents and spills	chemicals: transportation storage location and design of plants use of fertilizers salting roads in winter	bioaccumulation of toxics genetic engineering energy intensive choices in life styles--buying bulk vs. small packages wrapped many times gap between medical and technical capabilities and social and legal development-life support systems; embryo transplants	acid rain soil erosion due to cultivation techniques pollution of water table irrigation and salt deposits orbiting space junk cultural impact of technological capabilities, such as supplying water to nomadic societies

2. for students to gather relevant data to investigate an identified social, environmental, or technological problem using primary sources

   i.e. analyzing water, soil, and air samples
   interviewing plant managers and technicians, etc.
   counting trains or trucks with chemicals

   and using secondary sources

   i.e. journals and magazines
   environmental impact statements
   governmental reports

3. for students to evaluate reliability of their sources of information

   i.e. government sources
   television, industrial reports
   newspapers and magazines
   individual opinions

4. for students to analyze problems, form opinions, or propose solutions regarding social, environmental, and technological issues

   i.e. what is the valid relevant information? Do you need other information?
   what are the possible interpretations of the implications from the information?
   How does the information affect your opinion on the issue?
   what are some possible resolutions of the issue or solutions to the problem?
   what additional information would be desirable?
   what would change your opinion?

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GOAL #2: DEVELOP SKILLS IN MANIPULATING MATERIALS AND EQUIPMENT, AND IN GATHERING AND COMMUNICATING SCIENTIFIC INFORMATION.

OBJECTIVE: A. Assemble and handle lab apparatus, tools, materials, and living organisms in a skilled and responsible manner, giving due attention to accident prevention.

LEARNER OUTCOME:
1. Manipulate in a safe manner appropriate materials, apparatus and equipment.
2. Acquires and assembles appropriate science apparatus, materials, and equipment in order to obtain designated data.
3. Proper and safe disposal of all laboratory waste.
4. Maintain appropriate life supporting environment for laboratory organisms.
5. Cares for and uses organisms in a responsible and legal manner.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
The teacher should provide opportunities:			
1. a. to demonstrate the proper technique and safe handling of equipment and materials			
b. for demonstration of the use of safety equipment such as an eyewash station, fire extinguishers and personal safety equipment			
c. for posting safety rules, charts, and posters			
d. for students to observe the teacher modeling personal safety procedures such as the wearing of safety goggles			
e. for school districts to anticipate a budget for the purchase and maintenance of lab equipment and materials safely			
2. a. to monitor the assembly and use of laboratory equipment			
b. for providing the maximum opportunities for students to construct and manipulate equipment and materials			
3. a. to give procedures for the proper and safe disposal of all lab wastes using labeled waste containers in the lab as appropriate--The wastes will then be dispursed in a manner consistent with the current directives in waste management.			
b. to establish procedures for cleanup in case of accidents or spills			
4. to properly and responsibly care for classroom organisms			
N/A	N/A	i.e. for students to keep organisms in a clean and non-stressful environment.	space simulation and other experiments are to be conducted with regard to safety and preservation of any living organism being used for instructional purposes.
5. to use established procedures when using organisms			
N/A	N/A	i.e. for students to become aware of established guidelines from organizations such as NSTA and NABT regarding the care of experimental animals. Teachers should be sensitive to the emotional needs of students when dealing with organisms.	

GOAL #2: DEVELOP SKILLS IN MANIPULATING MATERIALS AND EQUIPMENT, AND IN GATHERING AND COMMUNICATING SCIENTIFIC INFORMATION.

OBJECTIVE: B. Gather qualitative and quantitative information.

LEARNER OUTCOME: 1. Gather information that has been generated from a variety of sources.
2. Measure accurately using standard metric (SI) and the English systems of measurement.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE

The teacher should provide opportunities:

1. to gather information from sources such as:
   a. guest speakers
   b. journals
   c. textbooks
   d. public hearings
   e. direct experiences, experiments and observations

2. a. for instruction in the use of metric system, including the prefixes and subunits

   b. to use scientific notation and significant figures correctly when appropriate

   c. to accurately read instruments to appropriate level of precision

OBJECTIVE: C. Record observations accurately and organize data and ideas in ways that enhance their usefulness.

LEARNER OUTCOME: 1. Maintain an accurate record of primary data, recorded at the time of the observation.
2. Construct appropriate charts and tables to clearly illustrate the data in a systematic manner.
3. Use a computer to record, manipulate, and display data.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE

The teacher should provide opportunities:

1. a. for the use of appropriate charts, graphs, or data tables in order to record data at the time of observation

   b. for students to maintain a lab data notebook consistent with standard research documentation

2. for students to develop techniques needed to construct data charts, diagrams, tables, and graphs

3. a. for use of appropriate software for the recording, manipulating, and displaying of data

   b. to obtain hard copies of computer obtained data

GOAL #2: DEVELOP SKILLS IN MANIPULATING MATERIALS AND EQUIPMENT, AND IN GATHERING AND COMMUNICATING SCIENTIFIC INFORMATION.

OBJECTIVE: D. Apply appropriate mathematical concepts and skills in interpreting data and solving problems.

LEARNER OUTCOME:
1. Apply appropriate algebraic, geometric, and statistical techniques to manipulate data.
2. Use measured data to derive mathematical expsressions to describe phenomena.
3. Manipulate appropriate mathematical relationships to solve problems.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
The teacher should provide opportunities:			
1. to review math skills such as dimensional analysis and give examples of how the data can be manipulated through math procedures. Collect data and apply to:			
i.e. pendulum law Newton's laws	Perfect Gas Laws	population dynamics such as growth rate densities, and distribution	hydrostatic equation, heat capacity of water, latent heat of fusion and evaporation
2. for the student to manipulate data to generate a mathematical relationship, e.g.:			
i.e. centripetal force experiments, current, resistence and potential difference in electricity	Charles' Law Colorometric experiments	Enzymatic reactions vs. temperature changes	water wave speed experiment, absorption of light in water for different wave lengths; using P and S waves to determine the locus of an earthquake
3. to apply mathematical principles to solve problems in science, e.g.:			
i.e. calculates rates in motion experiments	Derive molar volumes from measurements of gas collected in a stoichiometric reaction.	calculates population trends from data-Hardy Weinberg equation; surface to volume ratios of cells	Calculate Doppler shift by measuring rate of shift toward the red end of spectrum.

OBJECTIVE: E. Communicate with others in a manner that is consistent with scientific reporting.

LEARNER OUTCOME:
1. Appropriately represent phenomena, relationships and explanations with words, equations, numbers and diagrams.
2. Use the appropriate level of written and oral skills to transmit self-generated and acquired knowledge to others.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
Teachers should provide opportunities:			
1. for students to choose proper vocabulary, equations or diagrams for the method which communicates the information most quickly, accurately, and is most easily understood, such as: a. the appropriate algebraic form to represent direct and inverse relationships b. use of slope-intercept form of a straight line equation to describe rate of change c. selecting diagrams, photos, and schematics to show relationships, and applications d. proper use of vocabulary to eliminate ambiguity and misunderstandings			
2. a. for the student to clearly and concisely describe the problem, observed data, and conclusions in both written and oral manner such as: i.e. After a lab activity, the student should be able to provide a clear statement of procedures used and outcome. Relate observed phenomena to concepts and principles. b. for the student to prepare a variety of scientific reports such as lab reports, oral presentations, current topic synopses, including abstracts and bibliographies			

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GOAL #2: DEVELOP SKILLS IN MANIPULATING MATERIALS AND EQUIPMENT, AND IN GATHERING AND COMMUNICATING SCIENTIFIC INFORMATION.

OBJECTIVE: F. Identify sources of error, inconsistencies in measurements and other threats to the validity of findings.

LEARNER OUTCOME:
1. Evaluate the methodology of the experiment, in problem solving, etc. as to its appropriateness.
2. Ability to calibrate instruments.
3. Ability to apply appropriate statistical methods to determine fitness of data.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE

The teacher should provide opportunities:

1. a. to discuss with students varied approaches to the problem, and the type of equipment and measurements that should be taken, prior to setting up the laboratory experiments

   b. to select one or more means of data collection consistent with equipment availability, and student background

   c. Evaluate results relative to anticipated outcomes.

   d. Evaluate level of precision and accuracy of instruments.

   e. for students to collect and report their data honestly and accurately

2. a. for instruction in instrument calibration

   b. to provide standards consistent with the requirements of calibration.

3. Provide models for the handling of data in order to evaluate it using procedures, such as: standard deviation, chi square, least squares, and linear regression, as appropriate.

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GOAL #3: DEVELOP AND APPLY RATIONAL, CREATIVE AND CRITICAL THINKING SKILLS.

OBJECTIVE: A. Acquire the ability to collect and process data.

LEARNER OUTCOME: 1. Skill development in gathering data.
2. Skill development in organizing and describing data
3. Skill development in comparing and evaluating data.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. a. Teacher will provide students with opportunities to decide what information is relevant and to recognize lack of needed information.			
b. Teacher will provide students with problems/situations that contain more information than is needed and lack of some needed information so that the student can discriminate observations from inferences, fact from opinion, etc.			
i.e. Observe electroscope leaves and infer conditions causing changes.	Candle burning. What do you observe? What can you infer?	Observe animal tracks and infer what animal made them.	Observe apparent motions of stars from earth and infer possible models to fit obser-
c. Teacher will provide students with opportunities to formulate their own questions and gather data to answer questions, designing and conducting their own experiments.			
i.e. Identify and investigate factors believed to affect friction. How measure friction? How to measure other factors?	Design and construct an Electro Motive Force (EMF) cell to produce a maximum potential difference and current for a specified minimum time.	Identify and investigate factors believed to affect a population of organisms.	Identify and investigate the factors affecting water holding capacity of soil or the speed of flowing water in a stream.
d. Teacher will provide students opportunities to measure, observe and record, and use numerical scales to order observations and measurements.			
2. Teacher will provide opportunities for students to: a. serially order data, b. translate data symbols into words, pictures, graphs, etc., c. heirarchically organize data, d. analyze data for range, average, median, mode, variance, standard deviation, etc., e. determine products or ratios of relevant quantities, f. describe properties of systems and subsystems, g. describe changes in properties, and h. describe relevant interactions.			
i.e. Represent the motion of an object using data table, words, strobe picture, graphs and gestures with hand.	For objects made of one substance, determine the mass and volume of each and determine the ratio of mass to volume for each.	Describe the sizes of members of the population and the numbers in various size ranges.	Design and apply a classification scheme for rocks. Design how to describe the distribution of area of a sea basin with depth.
3. Teachers will provide opportunities for students to: a. determine whether the quantitative property was more, less, or the same (i) from one time to another, or (ii) for one part of the system compared with another, b. compare averages of groups of data, c. seek consistency among forms of descriptions of data, and d. compare data and methods of describing data and demonstrate their rationale for explaining the results.			
i.e. How does the work we get out of the pully system compare with the work put into the system? Show how you decided.	Is the total energy of the system after the reaction the same as it was before the reaction? How do you know?	Are the sizes of the organism in one population significantly different from the size of that organism in another environment? How do you know?	How does annual rainfall in our state prior to eruption of a volcano compare with rainfall after? How did you define average rainfall?
Teacher will have students compare data by use of graphing techniques.			
i.e. Are your graphs, tables, words, and pictures describing the motion consistent with each other? How can you tell?	Are your graphs, tables, words, and pictures of data consistent with Boyle's Law?	Are your graphs, tables, words, and pictures describing the population change?	Are your graphs, tables, words, and pictures describing the precipitation patterns consistent?

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GOAL #3: DEVELOP AND APPLY RATIONAL, CREATIVE AND CRITICAL THINKING SKILLS.

OBJECTIVE: B. Acquire the ability to generate ideas.

LEARNER OUTCOME:
1. Students will learn to generalize ideas:
   a. infer visual, attributal, qualitative, or numerical patterns,
   b. synthesize observations into a new concept,
   c. synthesize new observations with an existing idea,
   d. invents the operations that define an idea (create an operational definition),
   e. generalize a conclusion from observations, and
   f. search for similar patterns in similar situations.
2. Students will learn to infer relationships:
   a. hypothesize a relationship between variables,
   b. infer a mathematically functional relationship, and
   c. infer a correlation of variables.
3. Students will learn to reason hypothetically:
   a. invent and/or use an analogy to bridge understanding,
   b. use inductive arguments to infer a conclusion,
   c. use deductive arguments to infer a conclusion, and
   d. use indirect rational argument to infer a conclusion.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. a.-f.			
Teacher will provide opportunities for students to generate new ideas and revise existing ideas. This takes time, but the skill of being able to generate new knowledge will be more necessary in the future. It is worth spending time developing the ability at the risk of not covering as much content. Because you are trusting the students to generate the ideas from their observations, be careful to choose experiments, equipment, and procedures that reliably will produce good results.			
It is critical at this stage to allow/encourage students to take risks, to make suggestions that will likely turn out to be revised. Students should be rewarded for making the effort at the risk of being wrong and answer the questions; What do your observations of . . . tell you about the nature of . . .? Are these new oservations consistent with our generalization from yesterday? In what way? If not, how do we need to revise our generalization?			
i.e. What common theme do you see in all the simple machines?)	What common theme do you see in periodicity? In atomic theory?	What common theme do you see in the species concept? What evidence do you have that man is a machine?	What common theme do you see in the comparison of weather with climate?
What evidence do you have that light behaves like a wave?)	What evidence do you have that electrons interact in chem. reactions?	What evidence do you have for natural control of population?	What evidence do you have that weather affects rock?
2. a.-c.			
Teacher will provide activities wherein students are expected to infer relationships.			
Under a constant acceleration in a straight line how is distance traveled related to time elapsed?	From all our experiments, what is the relationship between the amount of oxygen and the amount of hydrogen produced in electrolysis of water? What do you mean by amount here?	Does the possession of a trait correlate with the possession of any other traits? What is your evidence? How confident are you that a correlation exists?	What are some meteorological factors possibly affected by the eruption of a volcano? Why do you believe so?
3. a.-d.			
Teacher will encourage students to reason hypothetically.			
Can you come up with another system that is analogous and that can help us understand a new system?			
Describe the "if . . ., then" links in your argument.			
If your conclusions were <u>not</u> true, where would that lead you logically? Is there a contradiction?			

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GOAL #3: DEVELOP AND APPLY RATIONAL, CREATIVE AND CRITICAL THINKING SKILLS.

OBJECTIVE: C. Apply ideas and/or data to situations and problems.

LEARNER OUTCOME:
1. Apply learned ideas:
   a. seeks opportunities to apply learned ideas,
   b. applies learned ideas to given situations or problems, and
   c. identify problems or situations for which it would be appropriate to apply the learned idea.
2. Apply problem solving skills:
   a. fully describe the problem,
   b. identify which principles are relevant to a particular problem or situation,
   c. make an educated guess at solutions to problems,
   d. attempts a qualitative approach to the problem before using formulas and specific numbers,
   e. chooses an appropriate equation or set of equations for the particular problem,
   f. acts out conditions of the situation to seek a possible solution, and
   g. identify relevant and irrelevant variables in a problem/situation.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. a.-b. Teacher will provide students with many opportunities to apply ideas learned in class, and encourage students to apply ideas. i.e. We've been studying batteries and bulbs circuits in class. What does this have to do with the electricity in your home?	Apply the pH idea to the effects of soaps and shampoos used around the home.	What does the protein we've been studying have to do with your eating habits at home?	After seeing how the lighted portion of a sphere appears from various locations in a room, how might you apply this to describing phases of the moon?
1. c. Teacher will encourage students to identify situations in which learned ideas apply. i.e. Give several situations, for which ones does a particular principle apply?			
2. a.-d. Teacher will focus class activities on techniques for improved problem solving skills as well as obtaining a solution to the problem. Note: Students are generally more successful at solving a problem if they have first of all described the problem completely. (e.g. From the given information and any reasonable assumptions, tell me as much other information as you can about the situation.)			
2. e.-g. Teacher will provide activities that focus on describing a problem including (1) identifying relevant variables, data, and principles, and (2) developing approximate or qualitative solutions as well as developing a full precise solution. i.e. Given the following information about a situation, describe as much as you can about the situation, asking and answering your own relevant questions before you address the specific questions in the text.			

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GOAL #3: DEVELOP AND APPLY RATIONAL, CREATIVE AND CRITICAL THINKING SKILLS.

OBJECTIVE: D. Use procedures for checking generated ideas and solutions.

LEARNER OUTCOME:
1. Check experimental results by:
   a. suggesting or conducting a replication experiment,
   b. checking actual, experiment results against predicted results,
   c. revising a hypothesis on the basis of experiment results,
   d. suggesting a modeling situation to test results,
   e. revising experimental design to more accurately answer the question or test the hypthesis, and
   f. attempting to extrapolate the results to other situations to check their validity.
2. Check logical arguments by:
   a. considering assumptions, premises, and conclusions made in arguments,
   b. retracing steps followed to generate a conclusion or solution,
   c. working backwards through steps in an argument, and
   d. checking the validity of each "if, they" link in a chain of implications.
3. Check the solution to a problem by:
   a. checking the reasonableness of the solution,
   b. making an estimated or approximated solution to check the actual full solution,
   c. solving problems using more than one method,
   d. seeking multiple solutions in situations where they might exist,
   e. evaluating solutions to
      (i) determine if the solution is of value, and
      (ii) determine if the solution is the best one available, and
   f. checking dimensional units to see if answer is consistent.
4. Reflect on their own learning
   a. identifying when they understand and when they do not, and
   b. identifying what they understand and what parts they do not.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE

1. a.-f.

   Teacher will encourage students to note and resolve discrepancies between their personal, existing understanding and the specific results of the just performed experiment.

   This is another area where the teacher needs to be sensitive to students taking risks. If students are to be expected to change their own thinking, they need to feel comfortable discovering that their initial ideas were not correct. They will need time and be given continued opportunities to resolve discrepancies.

   i.e. Does *your* result make sense in light of your ideas? Are there difficulties with the experiment or with your initial ideas? What are you going to do about it?

2. a.-d.

   Teacher will explicitly ask students to describe their reasoning.

   What assumptions are associated with the equations you used to solve the problem?

   What assumptions and reasoning are you using when you apply these concepts on a larger scale?

   How did *you* come to that conclusion? Describe your reasoning.

   Consider providing students with critical examples of reasoning from the history of science, Galileo, Darwin, etc.

3. a.-e.

   Teacher will encourage students to check and evaluate their solutions.

   Does *your* answer seem reasonable?

   Solve the problems another way and compare your solutions?

   Can you suggest several possible solutions? What are they?

   Is the solution feasable? Is it a "good" solution? Which solution is the best under the circumstances.

   Do the units associated with the terms on one side of an equation match with the units of your answer?

4. a.-b.

   Teacher will provide students chances to reflect in writing on their own learning.

   On each problem/question indicate *your* level of confidence in your understanding of the related ideas?

   What do *you* need to know about in order to form an opinion or solve the problem?

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GOAL #3: DEVELOP AND APPLY RATIONAL, CREATIVE AND CRITICAL THINKING SKILLS.

OBJECTIVE: E. Anticipate future situations and problems.

LEARNER OUTCOME:
1. Predict future consequences of present actions by:
   a. applying cause and effect relationships.
   b. extrapolate present trends into the future,
   c. envision conditions in the future, and
   d. identify critical factors affecting conditions in the future.
2. Develops possible alternatives to solve anticipated problems:
   a. considers or invents possible future breakthrough in ideas on technology,
   b. consider possible impediments to proposed alternatives, and
   c. consider possible consequences of proposed solutions.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE

1. a.-d.

   Teacher will provide explicit opportunities to anticipate future consequences.

   i.e. Anticipate the soil capabilities to produce food under various agricultural policies and practices.

   Anticipate the possible consequences of the development of nuclear energy resources as opposed to presently used energy sources.

   Read outside of science to see the broad picture (mega trends, corporate structure, etc.)

2. a.-c.

   Teacher provides explicit opportunities to invent/suggest possible alternatives to solve existing or anticipated problems.

   i.e. opportunities to discuss impacts of present decisions on the future, such as: clearcutting the tropical rain forests will cause changes in (1) soil retention, (2) ecology of the area, and (3) amount of atmospheric CO_2

   opportunities to discuss causes of (1) world hunger, (2) energy issues, and (3) the way we spend our dollars for research

GOAL #4: TO DEVELOP VALUES, ASPIRATIONS, AND ATTITUDES THAT PROMOTE PERSONAL INVOLVEMENT OF THE INDIVIDUAL WITH THE ENVIRONMENT AND SOCIETY.

OBJECTIVE: A. Acquire a positive realistic self-concept.

LEARNER OUTCOME: 1. Achieve attitudes and behaviors of a self-directed learner.
2. Demonstrates and values personal decision making.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
1. The teacher should provide opportunities:			
a. for students to follow directions when given once;			
b. for students to work in the laboratory successfully with minimal supervision;			
c. for students to follow through on independent projects;			
d. to praise students who work well in a self-directed manner; and			
e. to reward students for staying on-task, carrying out independent projects, taking the initiative by proposing new avenues of study, going to science exhibits, movies, or events, and reporting back.			
2. The teacher should encourage and praise students who demonstrate the ability to make personal decisions.			
a. for the analysis of personal values:			
i.e. funding for NASA vs. basic research	industrial employment vs. pristine environment	endangered species vs. land use	strip mining vs. environmental protection
b. for choices on term paper topics or reports;			
c. to reward students who perform at a level challenging their abilities or talents; and			
d. for open-ended activities with high success rates:			
i.e. Describe how the lever works.	Describe the process of combustion using a burning candle.	Describe the process of chromatography and its uses.	Describe the crystalline structure of a mineral.

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GOAL #4: TO DEVELOP VALUES, ASPIRATIONS, AND ATTITUDES THAT PROMOTE PERSONAL INVOLVEMENT OF THE INDIVIDUAL WITH THE ENVIRONMENT AND SOCIETY.

OBJECTIVE: B. Acquire awareness and appreciation of beauty and orderliness in nature.

LEARNER OUTCOME:
1. Encourage the desire to question, know and understand the natural world.
2. Encourages a sense of wonder about the environment.
3. Gains an appreciation and respect of living organisms and accepts responsibility for their care in natural and artificial environments.
4. Identifies patterns in color, form, texture, and arrangement to the design of objects in the environment in an attempt to understand order in nature.
5. Helps focus feelings about asthetic aspects of the natural and technological world.
6. Enjoyment of participating in scientific activities.
7. Respect for the process of that interdependence of living organisms that is necessary for their continued survival in the natural environment.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE

The teacher should provide opportunities:

1. to continuously observe phenomena, developing a questioning attitude toward understanding of the phenomena--Teachers should encourage an open environment where students are comfortable asking questions about their world.

2. to develop an appreciation of natural objects and events

3. to discuss the role of national parks, forests, monuments and wilderness areas

   a. to minimize impact on the environment during field studies

   c. for the student to properly care for living organisms in the classroom

4. a. to use appropriate visual aids to illustrate patterns in nature such as NASA photographs, electron micrographs, infrared photography, and holography

   b. for students to explore micro and macro patterns in nature

i.e. describes color patterns in rainbows, oil slicks, soap	Describe colors and crystal structure.	Describe patterns in leaf arrangements; universal use of ATP; dichotomous branching.	Describe wind patterns, ocean currents, rock stratification, crystal structure, and constellations.

5. for students to describe their feelings about the asthetic aspects of the natural and technological world after science activities such as field trips, movies and experiments

6. for students to develop and share science related hobbies and careers

7. to encourage a global, ecological perspective of interdependence between living organisms, including the role of humankind as stewards of the environment

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GOAL #4: TO DEVELOP VALUES, ASPIRATIONS, AND ATTITUDES THAT PROMOTE PERSONAL INVOLVEMENT OF THE INDIVIDUAL WITH THE ENVIRONMENT AND SOCIETY.

OBJECTIVE: C. Participate actively in identifying and solving societal problems related to science and techology.

LEARNER OUTCOME:
1. Develops cooperative skills in working within a group.
2. Strengthen attitudes towards conservation, preservation, and wise use of natural resources.
3. Helps people meet their responsibility in valuing environmental quality.
4. Ability to express an opinion on societal issues using knowledge of science and technology to support that opinion.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE

The teacher should provide opportunities:

1. a. for students to work effectively in small and large groups in labs on ecological work teams, and in discussion groups

   b. for students to use interpersonal skills to clarify ideas and understandings within a group

   c. for the student to assume different group roles such as leader, recorder, and reporter

2. a. to investigate means of harvesting natural resources such as ores, fuels, timber, shellfish, etc. with the least impact on the environment

   b. to consider and/or participate in the preservation of a natural object, species, resource, or ecological system

3. a. to investigate the impact of humans on the environment through such things as: pesticides, thermal power plants, hydroelectric power plants, hazardous waste disposal, sewage effluent discharge

   b. investigate the role of analytical science in measuring environmental variables such as, toxic substances in water systems and in the atmosphere

4. a. Use a data base from research to make decisions on technological impact on society, such as:

   i.e. nuclear energy | chemical plant design | artificial organs, genetic engineering | nuclear winter, acid rain

   b. Compare and contrast human use of resources or modification of the environment with natural cycles, such as: weathering, erosion, water cycle.

   i.e. Investigate governmental regulations pertaining to environmental quality such as National Environmental Policy Act, and the State Environmental Policy Act.

   Study an environmental impact statement.

GOAL #4: TO DEVELOP VALUES, ASPIRATIONS, AND ATTITUDES THAT PROMOTE PERSONAL INVOLVEMENT OF THE INDIVIDUAL WITH THE ENVIRONMENT AND SOCIETY.

OBJECTIVE: D. Acquire knowledge of the interrelationships between science, politics, economics, religion, and other aspects of culture.

LEARNER OUTCOME:
1. Value science as an activity of males and females from all racial, ethnic and cultural backgrounds.
2. Recognition that scientific investigations are affected by the value system of the observer.
3. Value science as a participant in the potential improvement of the Human condition.
4. Understand how politics, economics, and value systems influence what science investigation and technology develops.
5. Realize that scientific truths must be pursued through research even if unpopular or not immediately applicable.
6. Recognition that historical advances in science have been influenced by the cultural conditions of the time period.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE
The teacher should provide opportunities:			
1. a. to use nonbiased materials			
b. for students to read about or listen to males and females from varied cultural backgrounds and ethnic groups who have made contributions to science			
2. for the student to consider the influences of social value systems on scientific and technological areas of emphasis:			
i.e. defense of society and its values implies defense systems research, valuing of the preservation of human life implies medical life support systems research, and the desire for electrical power implies the generation and transmission of electric power along with its environmental costs.			
3. to consider the effect of research in improving the quality of human life:			
i.e. energy use to provide a higher standard of living	uses of plastics and other polymers	reduction of disease	technological application from the space program such as biomedical telemetry, erosion control
4. a. for students to identify ways in which various aspects of culture affect scientific research and technological development			
i.e. nuclear power plants	pesticide use, agent orange	genetic engineering	strip mining, off-shore drilling
b. to develop a debate or essay activity based on the positive and negative aspects of science discoveries			
5. to recognize that basic research may ask questions of nature, application of which may not be known immediately			
i.e. lasers and laser surgery	polymerization and development of synthetic fibers	DNA research and recombinant DNA	Ceramic engineering and space shuttle tiles

GOAL #4: TO DEVELOP VALUES, ASPIRATIONS, AND ATTITUDES THAT PROMOTE PERSONAL INVOLVEMENT OF THE INDIVIDUAL WITH THE ENVIRONMENT AND SOCIETY.

OBJECTIVE: E. Acquire appreciation for science related careers and science learning throughout ones life.

LEARNER OUTCOME:
1. Knowledge about the qualities of science related careers that satisfy human needs for creativity, high credibility, relevance, active participation and rewards.
2. Consideration of science as future oriented, preparing individuals for a more continuously relevant, effective, richer life.
3. Assume responsibility for making a realistic decision about the pursuit of a science related career by considering personal interests, attitudes, aptitudes, and career trends.

INSTRUCTIONAL IMPLICATIONS

PHYSICS	CHEMISTRY	LIFE	EARTH/SPACE

The teacher should provide opportunities:

1. a. to read biographies of scientists

1. b. to use references or field trips to local facilities that employ persons trained in science

2. to expose students to current scientific events through media such as newspapers, science publications, and TV, showing the relevance of science to everyday life

3. a. for students to examine a list of career choices and the requisites to achieve those careers, such as expenditure of time, academic preparation, and costs, in order to make career decisions

3. b. for students to explore scientific careers through a career day utilizing counselors, former students, and professionals in science fields

Bonaparte's Gull
Drawing by Tony Angell

APPENDIX A

DESCRIPTION OF SCIENCE PROCESS SKILLS

OBSERVING

The main route to knowledge is through observing using all the senses. It is a distinct process by which people come to know about the characteristics of objects and their interactions.

COMMUNICATING

Reporting observations and experimental procedures and results. Communciation may be oral or written and may involve the use of graphs, charts, diagrams and pictures.

COMPARING

Comparing is a distinct process by which people systematically examine objects and events in terms of similarities and differences. By comparing the known to something unknown, we gain knowledge about the unknown. All measurements are forms of comparing.

MEASURING

Developing a comparative or quantitative description of such properties as length, area, volume, weight, mass, temperature or speed.

ORGANIZING

Knowledge of principles and laws is gained only through the systematic compiling, classifying, and ordering of observed and compared data. Bodies of knowledge grow from long-term organizing processes.

COLLECTING DATA

Collecting and organizing information obtained through observation or reading. Preparing tables of data, constructing graphs.

CLASSIFYING

Recognizing patterns. Grouping or ordering objects or events based on common properties or existing relationships according to a scheme devised by the observer.

RELATING

Relating is a process by which concrete and abstract ideas are woven together to test or explain phenomena. Hypothetical-deductive reasoning, coordinate graphing, the managing of variables, and the comparison of effects of one variable upon another contribute to attainment of the "grand" ideas of science.

USING SPACE/TIME RELATIONSHIPS

Estimating the relationships of moving and of nonmoving objects to one another.

FORMULATING HYPOTHESES

Stating a probable explanation for some ocurrence which is subject to testing by one or more experiments.

IDENTIFYING AND CONTROLLING VARIABLES

Identifying what will vary or change in a given investigation. Setting up investigations that measure variables.

EXPERIMENTING

Experimenting is the process of designing data-gathering procedures as well as the process of gathering data for the purpose of testing a hypothesis. In a less formal sense, experiments may be conducted simply to make observations. However, even here there is a plan to relate cause-and-effect. In an experiment, variables must be identified and controlled as much as possible. An experimental test of a hypothesis is designed to indicate whether the hypothesis is to be accepted, modified, or rejected. In designing an experiment, limitations of method and apparatus must be considered.

INFERRING

The process of realizing ideas that are not directly observable is the process of inferring, and an inference is developed from a set of related observations. The process leads to predictive explanations for simple and complex phenomena. Arriving at a decision or opinion on the basis of observation and/or past experience requires evaluation and judgement.

PREDICTING

Using previous information to make decisions about what might happen in the future.

FORMULATING MODELS

Models, whether physical or mental, are devised on the basis of acceptable hypotheses or hypotheses that have yet to be tested. Models are used to describe the interrelationships of ideas. In many cases the model implies new hypotheses; if testing these hypotheses results in new information, the model must be altered to include it.

INTERPRETING DATA

Interpreting data requires the application of other basic process skills--in particular, the processes of inferring, predicting, classifying, and communicating. It is through this complex process that the usefulness of data is determined in answering the question being investigated. Interpretations are always subject to revision in the light of new or more refined data.

MAKING OPERATIONAL DEFINITIONS

Operational definitions are made in order to simplify communication concerning phenomena being investigated. In making such definitions it is necessary to give the minimum amount of information needed to differentiate that which is being defined from other similar phenomena. Operational definitions may be based upon the observable characteristics of the phenomena and upon the operations to be performed. Operational definitions are precise and, in some cases, based upon mathematical relationships.

APPLYING

Use of knowledge is the applying of knowledge. Inventing, creating, problem-solving and determining probabilities are ways of using information that lead to further information.

APPENDIX B

SELECTED RESOURCES

GENERAL REFERENCES FOR INSTRUCTION AND PLANNING

Daedalus, Journal of the American Academy of Arts and Sciences Vol 112, #2 Spring, 1983 (Entire issue on Scientific Literacy).

4 MAT AND SCIENCE, Bob Samples, Bill Hammond, and Bernice McCarthy, Excell, Inc., 1985.

Learning How to Learn, Joseph Novak and D. Bob Gowin, Cambridge University Press, 1984.

Reforming Science Education: The Search for a New Vision, Paul DeHart Hurd, Council for Basic Education Occasional Paper #33, 1984.

Five Kingdoms, an Illustrated Guide to the Phyla of Life on Earth, Lynn Margulis, Karlene Schwartz, W. H. Freeman Co., 1982.

PERIODICALS

American Biology Teacher, National Association of Biology Teachers, 11250 Roger Bacon Drive, Reston, VA 22090

Astronomy, AstroMedia Corp., 625 East St. Paul Avenue, P.O. Box 92788, Milwauee, WI 53202

The Earth Scientist, National Earth Science Teachers Association, c/o Dept. of Geological Science, Michigan State Unviersity, East Lansing, MI 48824

Educator's Guide to Free Science Materials, Educator's Progress Service, Randolph, WI 53956

Journal of Chemical Education, Circulation Service, 119 West 24th Street, 4th Floor, New York, NY 10011

Journal of Environmental Education, Heldref Publications, 4000 Albemarle Street NW, Washington, D.C. 20016

Journal of Geological Education, National Association of Geology Teachers, P.O. Box 368, Lawrence, KS 66044

Journal of Research in Science Teaching, National Association for Research in Science Teaching, John Wiley and Sons, Inc., 605 Third Avenue, New York, NY 10016

The Physics Teacher, American Association of Physics Teacher, Graduate Physics Building, State Univeristy of New York, Stony Brook, NY 11794

Science and Children, National Science Teachers Association, 1742 Connecticut Avenue, NW, Washington, D.C. 20009

The Science Teacher, National Science Teachers Association, 1742 Connecticut Avenue NW, Washington, D.C. 20009

Scince Activities, Heldref Publications, 4000 Albemarle Street NW, Washington, D.C. 20016

Sky and Telescope, Sky Publishing Corp, Harvard University Observatory, Cambridge, MA 02138

Washington Science Teachers Journal, c/o Dr. Robert Christman, Editor, Geology Department, Western Washington University, Bellingham, WA 98225

RESEARCH REPORTS

A Nation At Risk: The Imperative for Education Reform, The National Commisson on Excellence in Education, U.S. Department of Education, 1983

Academic Preparation for College: What Students Need to Know and Be Able to Do, The College Board, 1983

Educating Americans for the Twenty First Century, National Science Board Commission on PreCollege Education in Mathematics, Science and Technology, two volumes, National Science Board and the National Science Foundation, 1983

The Global 2000 Report to the President: Entering the Twenty First Century, The Council on Environmental Quality and the Department of State, Superintendent of Documents, 1981

PROCEEDINGS: A working Conference on Science Education for Handicapped Students, Helenmarie Hoffman, Editor, National Science Teachers Association, 1978

Research Within Reach: Science Education, David Holdzkom, Pamela Lutz, Editors, Research and Development Interpretation Service, Appalachia Education Laboratory, Inc., 1985

Tomorrow: A Report of the Task Force for the Study of Chemisty Education in the United States, The American Chemical Society, 1984

What Research Says to the Science Teacher, Four Volumes, The National Science Teachers Association, 1978-1982

SCHOOL SCIENCE SAFETY

Better Science Through Safety, Gerlovich, Jack and Downs, Gary E., Iowa State University Press, 1981.

Hazards in the Chemical Laboratory, Bretherick, L., 3rd ed., London Chemical Society, Royal Society of Chemistry Publishers, 1981.

Manual of Hazardous Chemical Reactions, National Fire Protection Association, 1980.

Manual of Safety and Health Hazards in the School Science Laboratory, National Institute for Occupational Safety and Health, U.S. Department of Health and Human Services, 1980.

Prudent Practices for Disposal of Chemicals from Laboratories, Committee on Hazardous Substances in the Laboratory, Commission on Physical Sciences, Mathematics and Resources, National Research Council, National Academy Press, 1983.

Science Safety for Elementary Teachers, Gary E. Downs and Jack A. Gerlovich, Iowa State University Press, 1983.

SUPPLEMENTARY RESOURCES

AAAS Science Books and Films, 1101 Vermont Avenue NW, 10th Floor, Box B, Washington, D.C. 20005.

AAAS Science Resources for Schools, 1776 Massachusetts Avenue NW, Washington, D.C. 20036.

The Challenge of the Unknown, Karol Media, 22 Riverview Drive, Wayne, NJ 07470

Seven free programs about mathematical problem solving in either video or 16mm film format: Situation, Information, Restatement Outcomes, Management, Estimation, Arguement.

ERIC/SMEAC Clearinghouse for Science, Mathematics and Environmental Education, The Ohio State University, 1200 Chambers Road, Columbus, OH 43212.

Heath Earth Science Teacher's Resource Book, Heath Life Science Teachers Resource Book, Heath Physical Science Teacher's Resource Book, D.C. Health and Company, Lexington, MA.

Mathematics, Engineering, Science Achievement, 353 LOEW MS-FH18 College of Engineering, University of Washington, Seattle, WA 98195

MESA is designed to increase the number of underrepresented minorities in mathematics, engineering and physical science related professions.

National AudioVisual Center, 8700 Edgeworth Drive, Capitol Heights, Maryland 20743-3701.

(34 AV programs in science education; federally produced AV materials at low cost.)

NSTA Directory of Science Education Suppliers, 1742 Connecticut Avenue NW, Washington, D.C. 20009.

Free directory with listings of companies which provide science equipment and supplies, media producers, and publishers of textbooks, tradebooks, and resource materials. Also included is a list of educational services, software buying tips, science material ordering checklist, and microcompuer software evaluation instrument.

Project Learning Tree, K-12 interdisciplinary supplementary curricula related to forests and trees c/o Washington Forest Protection Assn., Evergreen Plaza Bldg., Olympia, WA 98504.

Project Wild, K-12 interdisciplinary supplementary curicula about wildlife and habitat, c/o Washington Game Department, 600 North Capitol Way, Olympia, WA 98504.

The Search for Solutions, Karol Media, 22 Riverview Drive, Wayne, NY 07470.

Nine 18 minute programs in Video or 16mm film format on the following topics: Investigation, Evidence, Theory, Trial and Error, Patterns, Context, Modeling, Prediction Adaptation. (Free).

Sourcebook for Elementary Science, Harcourt Brace Javanovich, 757 Third Avenue, New York, NY 10017.

APPENDIX C

THE NATURE AND THE LANGUAGE OF SCIENCE

In order to assist the educator to portray the tentativeness of the human endeavor known as science, the following categories are displayed as a language reference base. Much of the data here reflect work done by M.B. Ogunniyi of the University of Ibadan, Nigeria, as he worked to explain the methodological inquiries of science to educators.

The terms concept, theory, and law are each analyzed from the frame of reference of its 1) definitions, 2) characterization, 3) function, and 4) how it could be formed. An extensive review was made of the philosophical literature relating to the nature of science and its language, and seven individuals emerged as providing the most influential insights. They are R. Carnap (C), C. G. Hempel (H), P. Frank (F), J. G. Kemeny (K), E. Nagel (Na), L. Nash (Ns), and K. Popper (P). Each statement on the following lists is coded with the philosopher's initial in parentheses. Where all philosophers agree, the statement is coded with (Z).

The source material for this appendix comes from an article by M. B. Ogunniyi, entitled "An Analysis of Prospective Science Teachers' Understanding of the Nature of Science," from the Journal of Research in Science Teaching Vol. 19, #1 pp 25-32 (1982), John Wiley & Sons, Inc., publisher. Data noted here is quoted with the kind permission of John Wiley & Sons, Inc.

CONCEPTS

DEFINITION:

Concepts are the meanings attached to scientific terms. (H)

Concepts are the meanings given to names, symbols or ideas about natural phenomena. (P)

CHARACTERIZATION:

Concepts can usefully be divided into three main classes: classificatory, comparative and quantitative. (C)

Concepts constitute the language of science. (F)

Concepts cannot be logically reduced to classes of experience (i.e., finite number of observable instances). (P)

Not all concepts can be operationally defined. (Z)

FUNCTION:

Concepts are scientific terms which convey special meanings and are used in the formation of laws and theories about regularities in nature. (H)

FORMATION:

Formation of concepts is attempted by the use of inductive methods. (C)

Concepts are invented (i.e. involve more than induction, but also imagination or leap). (Na)

Formulation of concepts is attempted purely by the use of deductive methods. (P)

Empirical concepts are terms which derived their meanings from observations of nature. (Z)

THEORIES

DEFINITION:

Theories help explain, predict or retrodict uniformity in natural phenomena. (H)

Theories are general propositions which are more credible than hypotheses but less credible than laws. (K)

Theories are confirmed Hypotheses. (K)

Theories are universally adequate systems of explanation. (Na)

Theoretical concepts are composed of nonobservables. (C)

Theories can never be explicitly defined on the basis of observational terms. (C)

Theories are "tools" that assist us in gaining knowledge about the world around us. (F)

Theories seek to explain regularities of natural phenomena and to afford a deeper understanding of the phenomena in question. (H)

CHARACTERIZATION:

Theories like physical tools, help organize "raw data." (Na)

Theories must contain at least one empirical concept in order to be understood. (Z)

Laws and theories cannot be proved to be true or false. (Popper would rather say that while laws and theories cannot be proved to be true, they can be falsified). (Z)

Without theories, we do not know what to observe. (F)

FUNCTION:

Theories are general assumptions or instruments used for conducting scientific inquiries. (Na)

Theories are postulational systems that describe natural events. (Na)

Theories function as correlative and explanatory devices in the explanation of nature. (Na)

FORMULATION:

Theories are formulated through the use of inductive methods. (K)

Theories are derived from hypotheses of highest credibility on the basis of observations. (K)

Theories are created through imaginative insights of certain scientists. (Na)

LAWS

DEFINITION:

Laws are statements of approximation asserting uniformity in natural phenomena. (H)

A law is a description of records of events which occur in nature. (K)

Empirical laws are inductive generalizations about natural phenomena. (Na)

Laws are linkages between related natural phenomena or events. (Na)

CHARACTERIZATION:

Some laws in science contain theoretical concepts, but no empirical concepts. (C)

Laws are only proved or confirmed by their consequences. (C)

Laws make plausible to us why certain natural phenomena take place in certain ways and not in others. (F)

Laws in an empirical sense confirm truth about experience. (H)

Laws may be considered to be true statements, but theories can only attain different degrees of credibility. (K)

Empirical laws possess determinable empirical content. (Na)

Laws and theories are falsifiable but not verifiable. (P)

Laws and theories cannot be proved to be true or false. (Popper would rather say that while laws and theories cannot be proved to be true, they can be falsified). (Z)

FUNCTION:

Laws are synonymous with hypotheses or theories and are probable statements of postulates that explain physical regularities or observable physical effects. (P)

Laws and theories are used to explain facts (observations). (Z)

FORMULATION:

Laws are products of the human mind arrived at through induction or imagination. (F)

Laws are inductively formulated although the steps of the logical processes are not well known.

Empirical or experimental laws are formulated by using indictive methods. (Na)

Laws are human inventions. (Na)

Laws are formulated purely by deductive methods. (P)

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